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ANNALS *of* SURGERY

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STUDIES IN BONE TRANSPLANTATION; A STUDY OF A METHOD OF INCREASING THE OSTEOGENETIC POWER OF A FREE BONE TRANSPLANT

BY BARNEY BROOKS, M.D.

WITH THE COLLABORATION OF PAUL FUNKHOUSER, O. S. KREBS, AND F. C. HOWARD

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IN a series of experiments, which have already been reported,[1] it was shown that sodium alizarine sulphonate is a specific vital stain for growing bone. If a solution of this dye is injected intraperitoneally into animals at repeated intervals all bone which is formed during the period of the injections is stained a bright red color. This experimental method makes it possible to observe accurately the site and the amount of all new bone formed during any given period of time.

In a second series of experiments, also previously reported,[2] in which this method of study was used, it was found that the power of regeneration of new bone was limited to the periosteal and endosteal surfaces of the free living bone transplant. If the periosteal and endosteal surfaces of the transplant were completely removed, no bone grew from the transplant.

It was further observed in these experiments that in certain instances autogenous bone transplants with periosteum and endosteum failed to regenerate bone. All such instances were experiments in which old animals were used. It was stated that the power of regeneration of bone in a free bone transplant varies with the age of the individual, and that free transplants of bone result in a considerable proportion of failures if old animals are used.

The object of the experiments described in this paper was to test the value of a method of increasing the osteogenetic power of the autogenous bone transplant, in order that a defect in the shaft of a bone of an old animal could be bridged by a free bone transplant with a better prospect of the ultimate successful regeneration of the defect.

EXPERIMENTAL METHOD

Dogs were used as experimental animals. The oldest animals available were used. Before beginning each experiment the age of the dog was estimated by observing the state of preservation of the teeth, and the general

[1] Brooks: ANNALS OF SURGERY, June, 1917.

[2] Brooks: ANNALS OF SURGERY, Dec., 1917.

appearance and activity of the animal. It was possible at the end of each experiment to estimate the age of the animal more accurately by observing the relation of the epiphyses and the diaphyses of the long bones. This examination at least makes it possible to classify dogs according to age into young, adult and old. The presence of the epiphysial cartilage shows definitely that the dog is a young animal. No such animal was used in these experiments. In some of the dogs of these experiments it was observed that all traces of the junctions of the diaphyses and epiphyses were absent and the bones were hard and brittle. These instances were considered as old animals. In a few instances it was observed that although the epiphysial cartilages were completely absent the junctions of the epiphyses and diaphyses were plainly marked. Such animals were considered as adult dogs not particularly old. The use of the vital stain also made it possible to estimate the ages of the animals. The administration of this dye to young animals results in the staining of all bones of the body, while in the case of animals which have reached the age in which active growth of the bones has ceased, no such general staining of the bones takes place. In these experiments there was in no instance general staining of the bones by the vital stain.

The operative procedure was the same in all experiments except in a few details which will be indicated in the description of the individual experiments. Each animal had two operations, which for purpose of clearness will be referred to as "first stage" and "second stage" operation.

The first stage operation was as follows: After the usual skin preparation an incision was made in the lateral surface of the left thigh and the shaft of the femur was exposed. With a motor twin saw parallel incisions 4 mm. apart and 6 cm. long were made through the cortex of the shaft of the femur. Great care was taken not to strip away the periosteum between the saw cuts. The wound was then carefully closed. The skin sutures were removed on the third day after operation.

The second stage operation was in most instances done on the seventh day after the first stage operation. The animal was again anæsthetized and the skin of both forelegs and both thighs was prepared for operation. Incisions were then made in both forelegs and 4 cm. of the shaft of each ulna was resected. Great care was used to remove the sections of bone with all the periosteum. This can be done easily if the interosseus membrane between the ulna and radius is divided before beginning the resection of the ulna.

The wound in the left thigh was then opened and the femur exposed. Transverse saw cuts were made in the shaft of the femur at the ends of the parallel incisions which had been made at the previous operation. The bone transplant was then easily freed with a knife. The transplant showed marked thickening of the periosteum and there was evident new bone formation along the periosteal and endosteal surfaces. This transplant was used to bridge the defect in the left ulna.

An incision was then made in the right thigh and the femur exposed.

With a motor twin saw another transplant 4 mm. wide and 6 cm. long was removed from the shaft of the right femur which had not been subjected to previous operative injury. Great care was used not to strip away the periosteum from the transplant. This transplant was used to bridge the defect in the right ulna.

All wounds were closed. Both forelegs were dressed with plaster dressings.

Beginning on the 14th day after the second operation, the animals were given intraperitoneal injections of 3 cc. of a 5 per cent. solution of sodium alizarine sulphonate twice each week until the end of the experiments. The animals were sacrificed at the end of periods of 23 to 173 days after the second operation, and bones of the extremities removed for study.

This experimental method gave in each experiment two free bone transplants which were used to bridge similar defects in the shafts of the bones of an old animal. The transplant which was used to bridge the defect in the right ulna was cut from a bone in its normal quiescent state. The transplant which was used to bridge the defect in the left ulna was removed from a bone which was producing new bone in response to previous injury. Stated from another viewpoint, the transplant which was used to bridge the defect in the left ulna was partially cut in such manner as not to interfere with its nutrition and left *in situ* until it began to grow and then transplanted. The defect in the right ulna was bridged by a graft which was then not in a state of active growth.

The use of the vital stain made it possible to determine the site and amount of all new bone formed from the transplants.

In all experiments, the operative procedures were carried out with the animal in complete surgical anæsthesia. Careful aseptic technic was used. In all experiments included in this paper, the wounds healed without infection. Every effort was made to prevent pain and suffering in the experimental animal. In three instances wound infection followed operation. In two experiments fracture of the femur followed the operation. These animals were sacrificed immediately. In three other experiments the animals died of pneumonia before sufficient time had elapsed after operation to make the experiment of value. All animals were sacrificed by the administration of chloroform.

Experiments

Experiment No. 30.—Dog No. 35.—July 8, 1918.

Apparently old animal. Weight 10.5 K. First stage operation on left femur.

July 15, 1918, 7 days, second stage operation. Transplant from left femur used to bridge defect in left ulna. Transplant from right femur used to bridge defect in right ulna.

August 7, 1918, 23 days, dog died of general peritonitis following intraperitoneal injections of vital stain.

Examination of the bones indicated that the animal was an old dog.

All epiphyses united. All traces of epiphysial lines had disappeared. No general staining of bones by vital stain.

Left foreleg: Transplant in good position. Firmly united to stumps of resected bone by fibro-cartilaginous callus. There was a large amount of new bone formed along the entire endosteal and periosteal surfaces of the transplant. There was also new bone formed from the stumps of the resected bone and under the periosteum of the radius in the region of operation.

Right foreleg: Transplant in good position. Graft lay loosely in the surrounding tissues. Evidently entirely necrotic. No bone growth from the transplant (Plate I, Fig. 1).

Experiment No. 29.—Dog No. 56.—July 6, 1918.

Apparently old dog. Teeth worn. Gray hairs about mouth. Weight 10 K. First stage operation on left femur.

July 13, 1918, seven days, second stage operation. Transplant from left femur used to bridge defect in left ulna. Graft from right femur used for defect in right ulna.

August 9, 1918, twenty-seven days, dog died from anæsthetic during injection of vital stain.

Examination of bones indicated that the dog was an old animal. All epiphyses united and all traces of epiphysial lines had disappeared. No general staining of bones by the vital stain.

Left foreleg: Transplant in good position. Bone growing along the entire endosteal surface of the transplant. Small nodule of new bone on periosteal surface near middle of graft.

Right foreleg: Transplant in good position. There was a small island of new bone on the periosteal surface of transplant near its proximal end. No other bone growth from the graft (Plate I, Fig. 2).

Experiment No. 38.—Dog No. 83.—July 12, 1918.

Apparently old dog. Gray about mouth. Teeth worn. Weight 12 K. First stage operation on left femur.

July 20, 1918, eight days, second stage operation. Transplant from left femur used to bridge defect in left ulna. Transplant from right femur used for defect in right ulna.

August 20, 1918, thirty-one days, dog dead of abscess in peritoneum following injection of vital stain.

Examination of the bones indicated that the animal was an old dog. All traces of the junctions of the epiphyses and diaphyses had disappeared. The bones were brittle. There was no general staining of the bones by the vital stain.

Left foreleg: The transplant was in good condition. It was united to the stumps of the resected ulna. There was new bone formation along the entire endosteal surface of the transplant. There was a nodule of new bone on the periosteal surface near the middle of the transplant.

Right foreleg: The transplant was in good position. There was no evidence of growth of bone from any part of the transplant (Plate I, Fig. 3).

Experiment No. 21.—Dog No. 8.—June 24, 1918.

PLATE I

FIG. 1

Left Right

FIG. 2

Left Right

Left Right

FIG. 3

Left Right

FIG. 4

Apparently adult dog. Did not appear old. Teeth good. Weight 5.5 K. First stage operation on left femur.

July 1, 1918, seven days, second stage operation. Transplant from left femur used to bridge defect in left ulna. Transplant from right femur used for defect in right ulna.

August 6, 1918, thirty-seven days, animal died from anæsthetic while receiving injection of vital stain.

Examination of the bones indicated that the animal was an old dog. The junction of the diaphyses and the epiphyses were not visible. There was no general staining of the bones by the vital dye.

Left foreleg: Transplant was in good position. It was united to the stumps of the resected bone. There was new bone formation along the entire endosteal and periosteal surfaces of the transplant.

Right foreleg: Transplant in good position. United to the stumps of the resected bone. Bone growth along the entire endosteal surface of the transplant. Small islands of new bone formation along the periosteal surface.

The amount of new bone formed from the transplant in the defect in the right ulna was less than that formed from the transplant in the defect in the left ulna (Plate I, Fig. 4).

Experiment No. 4.—Dog No. 11.—April 4, 1918.

Animal apparently adult animal. Does not seem old. First stage operation on right femur.

April 25, 1918, twenty-one days, second stage operation. Transplant from right femur used to bridge defect in right ulna. Graft from left femur used for defect in left ulna.

June 4, 1918, forty days, animal did not have injections of vital stain.

Examination of the bones indicated that the animal was an adult dog. All epiphysial cartilages had disappeared, but the junctions of the epiphyses and diaphyses could be plainly seen.

Right foreleg: Transplant in good position. Firmly united to the stumps of the resected bone. Distinct bone growth along the entire transplant.

Left foreleg: Transplant in good position. Firmly united to the stumps of the resected bone. There was new bone formation along the entire length of the transplant.

There was no noticeable difference in the amount of bone formed by the two transplants.

Experiment No. 15.—Dog No. 61.—June 19, 1918.

Apparently old dog. Teeth worn. Weight 7 K. First stage operation on left femur.

June 26, 1918, seven days, second stage operation. Transplant from left femur used to bridge defect in left ulna. Graft from right femur used for defect in right ulna.

August 23, 1918, fifty-eight days, dog emaciated. Sacrificed.

Examination of the bones indicated that the animal was an old dog. All traces of the epiphysial lines had disappeared. There was no general staining of the bones by the vital dye.

Left foreleg: The transplant was in good position. It was firmly united by bone to the stumps of the resected ulna. There was bone growth along the entire length of the graft.

Right foreleg: The transplant was in good position. It was united to the distal stump of the ulna by bone and to the proximal stump of the ulna by fibrous tissue. There was growth of bone along the entire length of the transplant. The amount of new bone formed from the transplant was distinctly less than that formed from the transplant in the defect of the left ulna (Plate II, Fig. 6).

Experiment No. 1.—Dog No. 47.—February 27, 1918.

Apparently old dog. First stage operations on left femur.

March 18, 1918, nineteen days, second stage operation. Transplant from left femur used to bridge defect in left ulna. Graft from right femur used for defect in right ulna.

May 20, 1918, sixty-three days, animal in good condition. Sacrificed.

Examination of bones indicated that the animal was an old dog. All traces of the junctions between epiphyses and diaphyses had disappeared. Bones brittle. No general staining of bones by vital stain.

Left foreleg: The transplant was in good position. Graft firmly united to the stumps of the resected ulna. There is abundant growth of new bone along the entire length of the transplant.

Right foreleg: The transplant was in good position. It was not united to the stumps of the resected bone. There was no growth of bone from the transplant (Plate II, Fig. 5).

Experiment No. 39.—Dog No. 84.—July 12, 1918.

Apparently adult dog. Does not seem old. Teeth well preserved. Weight 14 K. First stage operation on left femur.

July 19, 1918, seven days, second stage operation. Transplant from left femur used to bridge defect in left ulna. Transplant from right femur used for defect in right ulna.

September 22, 1918, sixty-four days, dog dead of unknown cause.

Examination of the long bones showed all epiphyses united. There was no general staining of the bones by the vital stain.

Left foreleg: The transplant was in good position. It was united firmly to the stumps of the resected ulna. There was a large amount of new formed bone along the entire endosteal surface. There was also growth of bone along the periosteal surface.

Right foreleg: The transplant was in good position. It was loosely united to the stumps of the resected ulna by fibrous tissue. The transplant was about half its original size. All surfaces were rough. There was a small nodule of new bone at the middle of the transplant. It was not possible to distinguish the periosteal and endosteal surfaces of the transplant. There was such a small amount of growth of bone from the graft that it seemed unlikely that the defect would have ultimately been regenerated.

Experiment No. 3.—Dog No. 61.—March 20, 1918.

Apparently old dog. First stage operation on left femur.

April 4, 1918, thirteen days, second stage operation. Transplant

PLATE II

FIG. 5

Left Right

Left Right

FIG. 6

from left femur used to bridge defect in left ulna. Transplant from right femur used for defect in right ulna.

June 5, 1918, sixty-five days, animal in good condition. Did not have injections of vital stain.

Examination of the long bones shows all epiphyses united. The junctions of the epiphyses and diaphyses were not visible.

Left foreleg: The transplant was in good position. It was firmly united to the stumps of the resected ulna. There was growth of bone along the entire transplant.

Right foreleg: The transplant was in good position. There was growth of bone along the entire transplant.

There was no apparent difference in the results of the two transplants.

Experiment No. 2.—Dog No. 88.—February 27, 1918.

Apparently old dog. First stage operation on right femur.

March 28, 1918, twenty-nine days, second stage operation. Transplant from right femur used to bridge defect in right ulna. Transplant from left femur used for defect in right ulna.

June 5, 1918, sixty-nine days, animal in good condition. Sacrificed.

Examination of the bones showed all epiphyses united and the junctions of epiphyses and diaphyses were not visible. There was no general staining of the bones by the vital stain.

Right foreleg: The transplant was in good position. It was firmly united to the stumps of the resected ulna. There was growth of bone along the entire length of the transplant.

Left foreleg: The transplant was in good position. It was firmly united to the stumps of the resected ulna. There was growth of bone along the entire length of the transplant. The amount of new bone formed, however, was distinctly less than that formed from the transplant in the defect in the right ulna.

Experiment No. 42.—Dog No. 87.—July 26, 1918.

Apparently adult dog. Did not appear old. Teeth well preserved. First stage operation on left femur.

August 6, 1918, eleven days, second stage operation. Defect in left ulna bridged with transplant from left femur. Transplant from right femur used for defect in right ulna.

October 29, 1918, seventy-nine days, animal in good condition. Sacrificed.

Examination of bones showed all epiphyses united and all traces of the junctions of epiphyses and diaphyses absent. No general staining of bones by vital stain.

Left foreleg: The transplant was in good position. It was firmly united to the stumps of the resected bone. There was growth of bone along the entire endosteal and periosteal surfaces of the transplant.

Right foreleg: The transplant was not in good position. The distal end of the transplant was united to the distal stump of the resected ulna. The proximal end of the transplant was displaced so that it lay in contact with the radius. Along the proximal half of the transplant there was a large amount of new formed bone which was continuous

with new bone which had grown from the shaft of the radius. The distal end of the transplant showed much less new bone formation.

There was a larger amount of bone growth in the defect in the right ulna than was present in the defect in the left ulna.

Experiment No. 41.—Dog No. 86.—July 26, 1918.

Apparently old dog. Teeth worn. Weight 11 K. First stage operation on left femur.

August 2, 1918, seven days, second stage operation. Defect in left ulna bridged with transplant from left femur. Transplant from right femur used for defect in right ulna.

November 8, 1918, ninety-four days, animal in good condition. Sacrificed.

Examination of the bones indicated that the animal was an old dog. All traces of the junctions of the epiphyses and diaphyses absent. No general staining of the bones by the vital stain.

Left foreleg: Transplant in good position. Firmly united to the stumps of the resected bone. There was growth of bone along the entire length of the transplant.

Right foreleg: The transplant was in good position. It was united to the stumps of the resected bone. The transplant was much smaller than at the time of transplantation. There was growth of new bone at both extremities of the graft. There was distinctly less growth of bone from the transplant in the defect in right ulna than from the transplant in the defect in the left ulna.

Experiment No. 32.—Dog No. 77.—July 9, 1918.

Large adult male. Did not seem particularly old. Weight 13.5 K. First stage operation on left femur.

July 16, 1918, seven days, second stage operation. Defect in left ulna bridged with transplant from left femur. Transplant from right femur used for defect in right ulna.

October 29, 1918, one hundred and five days, animal in good condition. Sacrificed.

Examination of bones showed all epiphyses united. There was no general staining of bones by the vital stain. The junctions of diaphyses and epiphyses faintly visible.

Left foreleg: Transplant in good position. Firmly united to the stumps of the resected ulna. There was growth of bone along the entire endosteal surface of the transplant. Also a small nodule of new bone formation on the periosteal surface near the middle of the transplant.

Right foreleg: Transplant in good position. United to the stumps of the ulna. There was growth of bone from the endosteal surface of the entire length of the transplant. There was a small amount of new formed bone on the periosteal surface at the ends of the transplant.

Experiment No. 33.—Dog No. 78.—July 9, 1918.

Apparently old dog. Teeth worn. Weight 11.5 K. First stage operation on left femur.

July 17, 1918, eight days, second stage operation. Defect in left

ulna bridged with transplant from left femur. Transplant from right femur used for defect in right ulna.

October 29, 1918, one hundred and five days, animal in good condition. Sacrificed.

Examination of bones indicated that animal was an adult dog. All epiphyses united. The junctions of the epiphyses and the diaphyses were fairly distinct. No general staining of the bones by the vital stain.

Left foreleg: The transplant was in good position. It was firmly united to the stumps of the resected ulna. There was growth of bone along the entire transplant.

Right foreleg: The transplant was in good position. It was firmly united to the stumps of the ulna. There was bone growth along the entire length of the transplant. The amount of new bone formed was less than that formed from the transplant in the defect in the left ulna.

Experiment No. 19.—Dog No. 88.—June 22, 1918.

Large adult dog. Did not appear particularly old. Weight 10.5 K. First stage operation on left femur.

June 29, 1918, seven days, second stage operation. Defect in left ulna bridged with transplant from left femur. Transplant from right femur used for defect in right ulna.

October 22, 1918, one hundred and fifteen days, dog emaciated. Has mange. Sacrificed.

Examination of bones showed that animal was an adult dog. There was slight general staining of the metaphyses of all the long bones. The epiphysial cartilages were absent. The junction of the epiphyses and diaphyses was plainly visible.

Left foreleg: The transplant was completely absorbed. There is new bone formation at the ends of the stumps of the ulna. No growth of bone in the defect.

Right foreleg: The transplant had entirely disappeared. No bone in the defect.

Experiment No. 31.—Dog No. 76.—July 8, 1918.

Apparently moderately old dog. Weight 9.5 K. First stage operation on left femur.

July 15, 1918, seven days, second stage operation. Defect in left ulna bridged with transplant from left femur. Transplant from right femur used for defect in right ulna.

November 8, 1918, one hundred and sixteen days, dog in good condition. Sacrificed.

Examination of bones showed all epiphyses united. Lines of junctions of epiphyses and diaphyses almost but not completely obliterated. No general staining of bones by vital stain.

Left foreleg: Transplant in good position. Firmly united to stumps of ulna. Bone growth along entire length of graft.

Right foreleg: Transplant in good position. Firmly united to distal stump of ulna. Loosely united to proximal stump by fibrous tissue. Only a thin piece of the original transplant remained. There is a small

amount of new bone formation from the transplant. The distal stump of the resected ulna was markedly atrophied.

Experiment No. 5.—Dog No. 73.—April 24, 1918.

Apparently adult dog. First stage operation on right femur.

May 6, 1918, twelve days, second stage operation. Defect in right ulna bridged by transplant from right femur. Transplant from left femur used for defect in left ulna.

October 14, 1918, one hundred and seventy-three days, animal in good condition. Was not given injections of vital stain. Sacrificed.

Examination of the bones indicated that the animal was an adult dog. Epiphyses united. The junctions of the epiphyses and diaphyses, however, were still well defined.

Right foreleg: Defect in the ulna completely regenerated.

Left foreleg: Defect in the ulna completely regenerated.

There was no noticeable difference in the results of the two bone transplants.

RESULTS

In each of these experiments two bone transplants were used. One transplant was cut from a bone in its normal state. The other transplant

Experiment No.	Days between first stage operation and second stage operation.	Days from second stage operation to end of experiment.	Result of ordinary bone transplant. +Successful. 0 Failure. ? Doubtful success.	Result of growing bone transplant. +Successful. 0 Failure. ? Doubtful success.	Estimated age of animal.	Remarks.
30	7	23	0	+	Old	
29	7	27	?	+	Old	
38	8	31	0	+	Old	
21	7	37	+	+	Old	More bone formed from growing bone transplant.
4	21	40	+	+	Adult	No difference in results of two transplants.
15	7	58	+	+	Old	More bone formed from growing bone transplant.
1	19	63	0	+	Old	
39	7	64	0	+	Old	
3	13	65	+	+	Old	No difference in results of two transplants.
2	29	69	+	+	Old	More bone formed from growing bone transplant.
42	11	79	+	+	Old	See discussion.
41	7	94	+	+	Old	More bone formed from growing bone transplant.
32	7	105	+	+	Adult	No difference in results of two transplants.
33	8	105	+	+	Adult	More bone formed from growing bone transplant.
19	7	115	0	0	Adult	See discussion.
31	7	116	?	+	Adult	
5	12	173	+	+	Adult	No difference in results of two grafts.

Type of bone transplant	Number of experiments	Successful		Doubtful success		Failure	
		No.	Per cent.	No.	Per cent.	No.	Per cent.
Ordinary transplant.....	17	10	58.8	2	11.7	5	29.3
Growing bone transplant.....	17	16	94.1	0	0	1	5.8

was cut from a bone which was producing new bone in response to a previous injury. The two types of transplants were made simultaneously under the same conditions in the same animal, and the results studied at the end of the same period. The results of the two types of transplants are summarized in the following tables:

DISCUSSION

These experiments are interesting in that they show a relatively large proportion of instances in which the ordinary bone transplant with periosteum and endosteum failed to regenerate a bone defect when the transplantations were made in animals which were not young. In many other experiments not included in this study it has been found that similar transplants of bone in young animals have been successful in almost every instance in which there was not some obvious reason, such as infection, for their failure. The experiments are particularly interesting in that they show that transplants of growing bone result in a much larger proportion of successes than the normal bone transplants.

The success or failure of a bone transplant obviously must be determined by both internal and external factors. The latent power of the osteoblasts to multiply and produce bone is an internal factor and would seem to depend on the intrinsic latent power of regeneration of the bone from which the transplant is taken. The adequate supply of nutrition for growth of the bone-producing cells must come from the bed into which the transplant is placed and is an external factor. There are also more complicated external factors which at present are not clear and the nature of which is suggested by the more or less indefinite terms, "functional demand," "stimulus to growth," "immunity of tissues."

Whether the failure of a relatively large proportion of free bone transplants in old animals is the result of internal or external factors is not clear. It would seem most probable, however, that it was the result of the low intrinsic osteogenetic power of the bones in advanced life. It is possible that further experiments with homogenous transplants from young to old and from old to young animals would answer this question. It is also not clear from these experiments whether the growing bone transplant is successful in a larger proportion of instances than the normal bone transplant, because it contains cells with greater power of growth or because the growing tissue with its numerous thin-walled vessels and tissue spaces more readily acquires nutrition from the bed in which the transplant is placed. It would

seem more likely that the latter is true. If this is so, then the transplants would possibly succeed in even a larger proportion of instances if the bed into which the transplant is to be placed were also stimulated to grow by previous operative procedure. Further experiments are necessary to determine this point.

Experiment No. 19 deserves special comment. In this experiment the animal was not particularly old. The transplantations were done with apparently the same technic as in other experiments. The operative wounds healed without any evidence of infection. Both types of transplants completely failed to show any evidence of bone regeneration, and the original transplanted bone was completely absorbed at the end of one hundred and fifteen days. The general condition of the animal was not the best as was shown by the mangy skin, yet in other animals this condition has not seemed to influence bone regeneration. It is possible that this animal is comparable to certain clinical cases in whom there is almost complete lack of regenerative power of the bones.

The results of these experiments have a particular bearing on the clinical treatment of a certain group of non-united fractures. In some instances fractures do not unite as a result of poor approximation of the fragments. In such cases there is not necessarily poor regenerative power in the fractured bone and union may follow the correct approximation of the fragments of the fractured bone. In other instances, however, there is non-union in spite of good approximation of the fragments. In such instances, the failure of the fracture to unite must be the result of poor regenerative power in bone. The results of these experiments bear particularly on the latter group of cases.

The method of treatment of such cases at present consists in the use of a free bone transplant to bridge the fracture. The bone transplant may be removed from one of the fragments and placed across the defect, *i.e.*, the so-called sliding bone graft, or the transplant may be taken from another bone. In the sliding bone graft method the transplant is certainly removed from a bone which has little power of regeneration. From these experiments it would seem, therefore, that such a transplant would have correspondingly little osteogenetic power and would fail in a considerable proportion of instances to regenerate bone to unite the fracture. We believe this statement is borne out by clinical experience with the application of this method. As regards the method of removing the transplant from another bone, we have seen, clinically, instances in which it seemed that the failure to regenerate bone was a condition not limited to bone in which the fracture failed to unite but was common to all the bones.

In these experiments in which only dogs well advanced in life were used and in which the bones showed power of regeneration less than that in young animals, the conditions were comparable to those existing in clinical cases of non-union of fracture as a result of poor regenerative power in the bones. The method of using transplants of growing bone resulted in so much larger

a proportion of successful results than those following the use of normal bone transplants that it would seem as if the clinical use of this method would be valuable.

Experiments similar to these with other tissues have been reported by Loeb. Loeb found that transplants of regenerating kidney tissue in the rabbit resulted in more extensive growth than transplants of non-regenerating kidney.[3] In other experiments, however, this investigator found that transplants of regenerating epithelium did not grow more extensively than transplants of non-regenerating epithelium.[4]

These experiments are interesting in relation to other experiments now in progress. It has been found that a defect in the bone of an old animal can be successfully repaired by bridging the defect with a homogenous transplant of bone taken from a young animal. Further experiments are in progress to determine the relative value of this method as compared with the method described in this paper.

In these experiments the growing bone transplants have been transplanted seven to twenty-nine days after stimulating growth. In other experiments not yet completed the period between the first stage operation and the second stage operation has been varied. It is probable that the chance of success of the graft depends on the length of this period. The determination of the relative power of the bone callus in its successive stages of growth and atrophy to further regenerate bone has an important bearing on the treatment of all fractures.

In conclusion I wish to thank Mr. E. H. Hashinger of the senior class of the Washington University Medical School for the illustrations of this paper.

CONCLUSIONS

1. Autogenous transplants of normal bone with periosteum and endosteum fail to regenerate successfully defects in bone in relatively large proportion of instances if such transplantations are done in animals well advanced in life.

2. Autogenous transplants of growing bone succeed in a much larger proportion of instances than autogenous transplants of bone not in the state of active growth or regeneration.

EXPLANATION OF PLATES

In all of the illustrations the bone which was regenerated during the period of the experiment is colored red. The results of the growing bone transplants are shown in the drawings of the bones of the left forelegs. The results of the normal bone transplants in the same animals are shown in the drawings of the bones of the right forelegs.

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[3] Loeb: *Anat. Record*, 1912, vi, 109.

[4] Loeb: Arch. f. Endwicklungs-mechanic d. Organism, 1917, xxiv, 638.

PLATE I.

Figure 1. Experiment No. 30. Twenty-three days. Showing complete failure of normal bone graft in right ulna. Large amount of bone regeneration from growing bone transplant in left ulna.

Figure 2. Experiment No. 29. Twenty-seven days. Showing small island of new bone on normal bone graft in right ulna. Abundant bone growth from growing bone transplant in left ulna.

Figure 3. Experiment No. 38. Thirty-one days. Showing bone regeneration from growing bone transplant in left ulna. No regeneration of bone from normal bone transplant in right ulna.

Figure 4. Experiment No. 21. Forty days. Showing regeneration from both types of transplants. More bone growth from growing bone transplant in left ulna.

PLATE II.

Figure 5. Experiment No. 1. Sixty-three days. Showing complete failure of the normal bone transplant in the defect in the right ulna. Complete regeneration of the defect in the left ulna as a result of the growing bone transplant.

Figure 6. Experiment No. 15. Fifty-eight days. Showing regeneration of bone from both types of transplants. More extensive growth from the growing bone transplant in the left ulna.

THE ADVANTAGES OF PICRIC ACID OVER TINCTURE OF IODINE FOR DISINFECTION OF SKIN

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In 1910 I read a paper before the New York Surgical Society on "Disinfection of the Skin by Tincture of Iodine."[1] This paper was based on a year's trial of the method, and the results obtained seemed to justify the claims of Grossisch for its employment. My paper stimulated a good deal of interest, certainly in local circles, and perhaps had something to do with the general adoption of the method.

Soon after the publication of the paper I had several cases in which the iodine produced very disagreeable caustic effects; so much so, that for a time I abandoned it. The asepsis resulting from the return to the former methods was disappointing by contrast and I subsequently resumed the use of tincture of iodine, being careful, however, to wash off the iodine with alcohol, at the end of the operation. This modification on the whole was satisfactory, and the caustic effect of the iodine was diminished. Cases, however, did occur which gave rise to a good deal of annoyance, and I have long been on the lookout for some other suitable agent.

While stationed at a British Casualty Clearing Station, in 1917, I became familiar with the use of picric acid, 5 per cent. alcoholic solution, as a substitute for tincture of iodine. The wounds did fully as well as with tincture of iodine. I saw no cases of irritation of the skin and I was assured by everyone that none ever developed. The method has for some time been the routine mode of disinfection of the skin in the British armies.

In my service at the New York Hospital I have only tried it out in about one hundred consecutive cases, but we are exceedingly pleased with it. In no case has any patient manifested the slightest tendency to skin irritation or evidence of any discomfort. I am firmly convinced that we have in this solution an agent which should replace tincture of iodine entirely, as it has all of its advantages and none of its drawbacks. It is also very cheap. Prior to its use on the operating table the skin can be shaved with soap lather and scrubbed with soap and water as much as may seem desirable. The same precaution should be exercised as with tincture of iodine—namely, the skin, after being painted, is allowed to become dry before the operation is begun.

[1] Annals of Surgery, vol. xliii.

POST-OPERATIVE PAROTITIS *

By John B. Deaver, M.D.
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Secondary parotitis, occurring after operation, though not unknown to early surgery, has received attention only since the more general application of abdominal surgery has been practised. While not a very frequent phenomenon, it is an interesting one and worthy of more study than has been accorded it. The first reported cases all followed ovariotomy or some other operation on the female generative organs. Paget, however, as early as 1886, reported on 101 cases of secondary parotitis, one-half (51) of which took place after operation on the upper abdomen—gastrotomy, enterostomy, as well as after herniotomies, colostomy, abdominal and umbilical tumors, and penetrating injuries of the abdomen. The other 50 per cent. followed operations on the female generative organs. While at the present time, and in our experience also, secondary parotitis occurs more frequently after operations on the genitalia, especially in the female, the relative proportion has been considerably reduced. In fact, it is my belief that the type of operation, that is to say, the organ or organs operated upon, plays a minor rôle in the phenomenon of post-operative parotitis. Cases occurring in my experience may be reasonably attributed either to peculiarities of the pathology encountered, to local conditions, or to post-operative wound infection.

It is a well-known fact that the parotid gland is more susceptible to inflammation than the other large salivary glands. This is to some extent explained by the anatomical relation of the buccal orifices of the excretory ducts of the gland. According to some authorities there is also a physiological explanation for the ease with which the parotid gland is attacked by inflammatory processes, namely, the absence in the parotid secretion of mucin, the presence of which in the secretions of the other salivary glands acts as a bactericidal agent and a protection against infection. W. Stuart Low has shown in an interesting way the retarding influence of mucin on bacterial growth. He observed that sterile solutions containing mucin remained sterile for some time on exposure to air and that bacterial growth was inhibited when mucin was added to culture media. This interesting hypothesis, however, is not generally accepted, since not all bacteriologists are convinced of the bactericidal nature of mucin.

Post-operative parotitis may be classed into three groups: metastatic, occurring only in pyæmic conditions; ascending parotitis due to ascending infection *via* the excretory ducts; and traumatic, the result either of direct pressure on the parotid gland or the forcible manipulation of the jaw by the anæsthetist during operation. It is my impression that these factors are

* Read before the Philadelphia Academy of Surgery, December 12, 1918.

not infrequently the cause of subsequent parotitis. We all know how, in some instances, during ether anæsthesia, there occurs difficulty in breathing, spasm of the muscles of the larynx, cyanosis, accumulation of mucus in the mouth, etc., and how in endeavoring to overcome this condition the anæsthetist carries the jaw forward by pressing against the angle of the jaw. Sometimes, indeed too often, this procedure is not carried out as gently as it should be. If it were possible to keep records of such faulty manipulation and how frequently it is followed by the development of trouble in the parotid gland, I venture to say my contention would receive considerable support. That trauma can take place in this way is readily understood in view of the anatomy of the region. The anterior of the two large processes of the inner surface of the gland passes into the back part of the glenoid fossa behind the articulation of the lower jaw, therefore it can readily be seen how injury to this process can occur. A more frequent traumatic factor, however, is that exerted through the fingers of the anæsthetist pressing on that part of the gland which extends downwards behind the angle of the jaw into the neck.

Infection may be carried to the gland by way of the lymphatics from diseases of neighboring structures, by way of the blood-stream, and by way of the excretory duct of the gland, Stenson's duct.

The latter route seems a very plausible one since it is well known that the mouth harbors numerous bacteria to the increased virulence of which, especially staphylococcus infection may be due.

The question of ascending infection has been carefully studied and from the microscopy of the same, as described by Bucknall,[1] we learn that the process is due to choking of the gland by débris containing micro-organisms which are the same as are obtained from cultures of the gland, its pus, the orifice of Stenson's duct and the oral cavity. While in view of the fact that to-day the asepsis of the mouth receives considerable attention before and after operation this theory may lose some of its practical value, the fact remains that infection can take place by this route.

It is interesting to note that in recent times the majority of the cases of secondary parotitis have occurred after severely infected conditions, appendicitis, peritonitis, perforating gastric ulcer, etc. In fact, next to ovarian cyst, perforating gastric ulcer is said to be the most frequent operative condition which is followed by secondary parotitis. This would be readily explained by increased absorption of the intestinal contents in such cases. In very plain language, I am inclined to say that the complication occurs most frequently from "dirty bellies" where infection has probably resided and been active for some time, and where, owing to incomplete or careless surgery secondary infection takes place. Why the latter sometimes chooses the parotid gland and so often does not, is not easily explained, except perhaps by the trauma, already referred to, or by individual disposition to affections of the gland in question. That such disposition exists is generally admitted.

[1] *Lancet*, 1905, ii, 1185.

And where it does exist the parotid gland would represent a site of minor resistance.

Sometimes the dryness of the mouth following anæsthesia is given as a contributing factor in post-operative parotitis. This might apply to the cases in which the complication occurs within a day or two of operation. But these are comparatively few, most of them taking place between the third and seventh post-operative days. On the other hand, the withdrawal of food by mouth and the resulting absence of oral secretions has also been assigned as a cause for the phenomenon. Indeed, a number of cases of parotitis are reported to occur during the starvation treatment in unoperated cases of (supposed) gastric ulcer. These cases might lend support to the theory of the bactericidal action of mucin. There seems little doubt, however, that interference with normal salivary secretion and with the protective action of the saliva as it drains down the ducts may be responsible for infection in such instances.

I am aware that I have merely touched upon various points in the consideration of this interesting phenomenon. I have done so in order to get opinions from the members of the association and with the hope that at some other time I may be able to give the question the study it deserves, or perhaps stimulate others to do so.

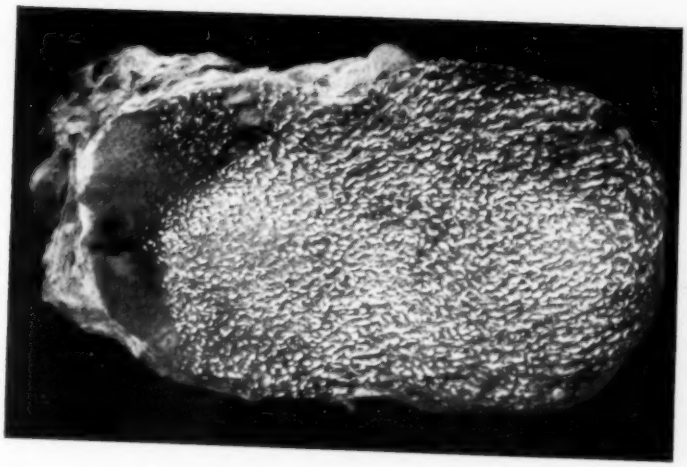

FIG. 1.—A typical "strawberry" gall-bladder.

FIG. 2.—Microscopic section of a "strawberry" gall-bladder showing subepithelial cells filled with a lipoid substance (stained with Sudan 3).

FIG. 3.—A section of an enlarged villus forming a papilloma which contains cells in the stroma similar to those in "strawberry" gall-bladders.

FIG. 4.—A gall-bladder showing normal mucosa, the "strawberry" condition and papillomas.

THE FREQUENCY OF "STRAWBERRY" GALL-BLADDERS *

By Wm. Carpenter MacCarty, M.D.
of Rochester, Minn.

An apology is due the medical profession for the introduction of such a term as "strawberry" in characterizing a definite pathologic condition in the gall-bladder. It came into usage, however, as a convenient colloquial, descriptive term as a result of a lack of a scientific name for a pathologic condition which has been frequently found since surgeons have been removing diseased gall-bladders, symptoms of which experience has taught them cannot be relieved satisfactorily by simple cholecystostomy.

In 1910 [2] the author studied a series of 365 gall-bladders which had been removed in the Mayo Clinic and presented the following grouping for the various stages of cholecystitis:

"*Group I: Cholecystitis Catarrhalis Acuta.*—In this group may be placed the gall-bladders which retain their general characteristics regarding size and color, both inside and outside; in other words, 'normal,' with the exception that the villi, congested and infiltrated with lymphocytes, are more prominent than normal. The infiltration may extend into the other layers of the wall. The condition occurs with or without stones. My attention was first drawn to this early condition by examination of a resected gall-bladder, which contained stones, but showed grossly no apparent change. Upon microscopic examination, however, the mucosa was infiltrated with lymphocytes and leucocytes. The diagnosis was sometimes made at operation by the thickened viscid bile, which seems to indicate hyperactivity of the glands of the mucosa and partial obstruction to the natural drainage. Other specimens in which no stones were found presented this same condition, and clinically gave a picture of cholecystitis. The stones which occurred in these cases were usually small, and may have been passed through the ducts in the cases in which none were found, or the condition may be the forerunner of stones. This early reaction of the mucosa was seen again in association with further changes, which constitute the second group.

"*Group II: Cholecystitis Catarrhalis Chronica.*—This condition varies from Group I only in degree, and one portion of the gall-bladder may belong to the first group and another portion to this group. The principal change grossly consists in an 'erosion' of the apices of the villi. These desquamated apices present themselves as yellow specks scattered over the mucosa. Otherwise the mucosa may appear normal or congested. This condition we have described as the 'strawberry' gall-bladder (Fig. 1) on account of the resemblance of the yellow specks to strawberry seeds. These have also been mistaken for fine stones. Microscopically, one sees that the epithelium

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is lost and replaced by scar tissue. Clinically, there is nothing to distinguish this group from Group I. It is found with or without stones.

"*Group III: Cholecystitis Catarrhalis Papillomatosa.*—In this group there was only one specimen. One of the villi was enlarged and appeared as a papilloma. The condition was associated with stones and an acute catarrhal reaction in the mucosa. The papilloma was 2 mm. long and about 1 mm. in diameter. The cells of the epithelium covering the villi and papilloma were regular in size and shape and possessed nuclei showing no irregularities.

"*Group IV: Cholecystitis Papillomatosa Malignum.*—Like papillomata in other portions of the body, these often undergo an irregular or perverted hyperplasia, which manifests itself in marked reduplication of the rows of epithelial cells. Upon high-power examination of the epithelial cells the chromatin granules are irregularly distributed; the nuclei are irregular in shape and size. These cells may or may not dip below the basement membrane. Such cases have been found during exploration, at which time portions of the gall-bladder were taken for examination. This type does not occur in this series because the cases seen were studied at exploration of inoperable cases.

"*Group V: Cholecystitis Catarrhalis Carcinomatosa.*—The neoplastic condition in the least advanced portions of the changed mucosa appears as knob-like outgrowths covered by epithelium which is in a stage of malignant hyperplasia, which differs apparently from simple hyperplasia morphologically in that the cells are irregular, undifferentiated and show invasive growth. There are areas, however, which contain glands, the nuclei of which are regular and indistinguishable from normal or hyperplastic glands. The more extensive outgrowths arise from the mucosa and possess a base not unlike that seen in the papilloma. The body of the growth is composed of masses of epithelium which, upon high-power examination, presents extensive irregularities in the size, shape, and distribution of the chromatin granules. Differentiation between this group and Group IV, Cholecystitis Papillomatosa Malignum, must be made with reserve, because it is possible that the one is but a stage of the other. No specimens in my series presented sufficient evidence for grouping both conditions under one heading. They present papillomatous outgrowths, differing only in shape. Those under Group V were knobs, while those in Group IV were filiform and less massive. Earlier stages of carcinoma of the gall-bladder must be found and studied before the life history of such perversions of the epithelium can be accurately pictured.

"*Group VI: Cholecystitis Chronica.*—In this group is placed a condition, gradual stages of which may be seen in specimens of Group II. The continued desquamation of the apices of the villi is associated with proliferation of the connective tissue of the villi and submucosa. The surface, which is normally regular, contracts irregularly and leaves ridges of scar tissue. Upon microscopic examination the inner surface is seen to be void of epithelium and the mucosa has been replaced by scar tissue. The process is not always complete over the whole gall-bladder, as a result of which areas

of the condition described in Groups I and II may be seen. It may occur at operation with or without stones. It has been classified under the term 'cholecystitis chronica' because the mucosa has almost completely disappeared and the process is a chronic one involving the other coats of the wall.

"*Group VII: Cholecystitis Chronica Cystica.*—A stone may become lodged in the cystic duct or in the valves of the neck of the gall-bladder and cause obstruction and distention of the organ. This results in the thinning of the wall and destruction of the mucosa or flattening of the scar tissue ridges in the chronic cases. The stone is usually firmly embedded between the valves and cannot be moved in either direction. Microscopically the wall is a thin layer of connective tissue in which traces of the nuclei of muscle-cells may be seen sometimes. Such a gall-bladder attains great size, and is usually the type which presents itself as a large palpable tumor.

"*Group VIII: Cholecystitis Purulenta Necrotica.*—During any stage of inflammation obstruction to the cystic duct may be so great, or the pyogenetic infection so virulent, that disturbance of the circulation or multiple abscesses in the gall-bladder may occur. The specimens are usually distended, dark blue or black, the contents pus or blood and usually not bile-stained.

"*Pericholecystitis Acuta and Chronica* must be considered a sequel to any of the above-mentioned degrees of inflammation. Even in the earliest degree of cholecystitis catarrhalis acuta the process may extend to the serosa through the lymphatics, and it is not infrequent to see adhesions, usually to the omentum and transverse colon, in this stage."

Since this classification was made over 5000 gall-bladders have been studied. No marked change has been made but such conditions as "strawberry" and papillomatous gall-bladders have become common occurrences.

It may be seen that the strawberry appearance was described as being due to "erosions" of the apices of the villi of the mucosa. This is an error as I believe is also the case in Moynihan's [3] description of the appearance as being due to minute deposits of stones. In his case the error was due probably to an insufficient number of cases for observation and a lack of detailed histological study of perfectly fresh specimens. In my own case it was undoubtedly due to the fact that I studied fixed specimens which had probably been extensively and perhaps harshly handled before they came into my hands. The epithelium was undoubtedly eroded in some advanced cases in the gradual pathologic process of erosion of the mucosa, but that the great majority of cases represent this condition is a mistake. The epithelium is intact and the appearance is due to the presence of a lipoid substance within the swollen connective-tissue cells which lie just beneath the epithelium (Fig. 2).

The villi may or may not be much larger than normal, although in many cases the villi are several times the normal in size. The condition may be present in one, many, or all of the villi. The villi are occasionally so large and branched that they form papillomas (Fig. 3) which may be single or

multiple (Fig. 4). Histologically such papillomas are identical with the villi of the "strawberry" gall-bladder, being merely larger and branched.

In a series of 5000 gall-bladders removed between October 17, 1911, and September 11, 1918, there were 936 (18+ per cent.) "strawberry" gall-bladders and 198 (4 per cent.) papillomatous gall-bladders.

A most interesting and important fact is the increased and relative frequency with which this condition has been noted since cholecystectomy has become a more common operation.

TABLE BY YEARS

	Number gall-bladders	Strawberry gall-bladders
1912	230	17 (7.4 per cent.)
1913	527	83 (15.8 per cent.)
1914	821	144 (17.54 per cent.)
1915	899	204 (22.69 per cent.)
1916	900	201 (22.33 per cent.)
1917	927	178 (19.2 per cent.)

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THE FREQUENCY OF ADENOMYOMA OF THE UTERUS *

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Since the publication in 1903 and 1908 of the excellent and complete monographs on the subject of adenomyoma of the uterus by Dr. Thomas S. Cullen, but few articles have been contributed to the literature. In view of the fact that his report contained only 73 (5.7 per cent.) adenomyomas in 1283 myomas of the uterus, and since these figures have not been confirmed by an equally large series, it seems timely to add a report from the Mayo Clinic.

Nothing in so far as gross and microscopic description or the origin of this condition can be added to what has already been so well presented.

Between 1906 and 1918 (October 1st) 3388 fibromyomatous uteri were removed in the clinic. Two hundred and eleven (6.43 per cent.) of these contained adenomyomas. In 5 cases the tumor was in the fallopian tubes. The frequency is somewhat greater in this series than in that of Cullen, but the figures are so close that from 5 to 7 per cent. expresses it safely.

The last 109 cases of the series were studied with reference to certain clinical features which might be intimately associated with the condition. Ninety-five patients (86 per cent.) were married; 41 per cent. gave histories of having had miscarriages, 50 per cent. suffered from profuse and prolonged uterine bleeding, and 31 per cent. from irregular bleeding. The average age of puberty was 14.3 years. Sixty-five per cent. of the married women had borne living children. In 5.5 per cent. of the cases epithelioma of the cervix or carcinoma of the body of the uterus was associated, neither of which conditions bore any apparent relationship to the adenomyomas. In 72 per cent. other pathologic pelvic conditions were associated, such as ovarian cysts, chronic or acute salpingitis, uterine or cervical polypi, cystic cervicitis or prolapsus uteri. In no case without the association of a malignant condition was the clinical diagnosis one of malignancy. In no case was a positive clinical diagnosis of adenomyoma made previous to operation. The clinical diagnosis was clothed in such terms as fibromyoma or pelvic tumor, both of which diagnoses show recognition of definite pathologic conditions of a neoplastic nature without attempting to specify in terms of detailed pathology.

The condition as related to years is as follows:

* Presented for publication January 29, 1919.

Year	Myomas	Adenomyomas	Adenomyomas in fallopian tube
1907	150	0	0
1908	154	6 (3.8 per cent.)	0
1909	198	6 (3 per cent.)	0
1910	213	8 (3.7 per cent.)	0
1911	228	18 (7.8 per cent.)	0
1912	231	12 (5.1 per cent.)	0
1913	274	21 (7.7 per cent.)	0
1914	316	22 (6.9 per cent.)	0
1915	348	23 (6.5 per cent.)	0
1916	386	37 (9.5 per cent.)	3
1917	378	36 (9.5 per cent.)	1
1918	301 (to Oct. 1)	22 (7.3 per cent.)	1
	3177	211 6.43 per cent.	5
	211		
Total,	3388		

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ABDOMINAL DRAINAGE *

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In looking over the statistics of the Harper Hospital of Detroit for the year ending December, 1916, we noticed there were 4412 operations done that year by general surgeons and gynæcologists.

Of this number there were 2652 abdominal sections. Of these 384, or 14 per cent., were done by gynæcologists and 2268, or 85 per cent.+, done by the general surgeon.

This shows conclusively that the tables have completely changed in the past twenty years. If this is a fair average of the hospitals of the country, it is certainly true of our Ohio Valley General Hospital in Wheeling, then we are to believe that the general surgeon is now doing more abdominal work than all of his other work combined.

It is for this reason that the writer was stimulated to take up this vital subject of abdominal drainage.

Although the question is an old one, there are still conflicting opinions as to when the peritoneum can be trusted to independently push back an invading foe from the abdominal salient.

There are those who will not hesitate to impose a heavy tax on this delicate membrane, and even in the face of greatly diminished body resistance, let the abdominal cavity do its own scavenger work.

The whole question is more or less dependent on the judgment and experience of the individual surgeon. Perhaps, after all, there has been ample justification for the cry against the promiscuous use of the iodoform tamponade of Briddon, the drain of Mikulicz, and the taxidermic methods of past years. But whether this radical anti-drainage teaching, with its far-reaching influence, has yielded the best results, is open to discussion.

In the Mütter [1] lectures on Selected Topics in Surgical Pathology, Roswell Park, quoted by Charles K. Briddon,[2] says: "Among all the defensive powers of the system, the capacity of resorption is, perhaps, the most important protection enjoyed by the cells and tissues composing the organism. This power seems to be enjoyed in the highest degree by the peritoneum, which is known sometimes to tolerate and dispose of relatively large amounts of infectious material."

Time and experience have not in the least detracted from this statement, made nearly thirty years ago. Park or Briddon, masters of that day, did not wish to be understood as saying that "the natural protection against

* Read before the Section in Surgery at the Annual Session of the West Virginia State Medical Association, October, 1918.

invasion of cocci was a warrant for the omission of any of the precautions that experience has proved to be useful." Indeed, the influence and tendency has been quite in accord with this fundamental teaching. This great capacity of the peritoneum for resorption, and its power to put up a stiff defense, has led the present-day surgeon to drain less and less.

When to Drain.—The tendency to dispense with drainage following peritoneal infection has led Doctor Munro [3] to formulate three interesting factors to be considered:

"1. The individual equation as regards susceptibility to infection. This factor cannot be determined by any known reliable method of examination. Judgment that comes with experience counts for much in estimating its value.

"2. The virulence of the infection. The species and the presence of the organism may be quickly and quite accurately determined by coverslip examinations. But this does not differentiate the virulence of the individual case.

"3. The presence or absence of distinct foci of infection. This cannot always be determined with safety or accuracy at the time of the operation. Consequently, if there is a reasonable doubt as to one of these factors we believe that some form of drainage is conservative."

Posture in Abdominal Drainage.—Posture has become a very important adjunct in the treatment of peritoneal sepsis, and, in passing, it is with grateful appreciation that we pay tribute to the memory of the founder of Fowler's position. The basic principle was established, that the most active and rapid absorption into the lymphatics takes place from the diaphragmatic and omental peritoneum, while the pelvic peritoneum is very slow to absorb (Munro). The demonstration of this fact led to Fowler's observation and the position which bears his name.

Hill [4] makes use of various positions in his abdominal work, to facilitate drainage, according to the location of the area of involved peritoneum. He employs the Fowler position, the prone or ventral decubitus and the lateral position. Certainly the position of the patient is an important factor in the recovery of the more severe cases of abdominal infection.

We wish to urge the importance of transporting a patient in the sitting position where a peritoneal sepsis is suspected. The writer has insisted on the observance of this step in bringing these patients from a distance to the hospital. Doctor Munro [5] has emphasized this step several years ago, and spoke of the cardiac weakness in patients of this class as being dependent on heart changes secondary to general septic absorption. If this toxæmia is minimized, rather than increased by posture of the body, there is less to be feared as regards circulatory shock and collapse.

War Wounds of the Abdomen [6].—Regarding the drainage of war wounds of the abdomen, Sir Anthony Bowlby in his splendid paper, "The Development of British Surgery at the Front," just published under the supervision of the British Medical Association, says: "Abdominal drainage is most probably of little use except in local lesions." In speaking of the statistics in the present campaign, he reports an operative mortality of 50 per cent., and

while such a report would be considered an awful death-rate in civil practice, it was considered good under existing conditions. As a consequence of the first shock of war falling on a peace-loving and unprepared people, and waged in mudholes, polluted with the manure of centuries, before the crusade against the murderous Hun was six months on the way, there began to be seen in the hospitals of France and England infections of a kind and severity unknown to surgeons trained in the Listerian era. But how very different are the present-day military and civilian problems in wound treatment.

Dr. C. L. Gibson [7] has said: "The treatment of war wounds is a highly specialized branch of surgery, and the rules of civil practice apply hardly, if at all, at the front." The seriously injured factory hand will come, as a rule, from clean surroundings, he has been properly fed and clothed, he has not been unduly exposed to cold and wet, and his body well rested when his injury is sustained. "The wounded soldier will probably have been subjected to harassing conditions of warfare. His injuries may be multiple. It may be some time before he is picked up and in addition to the other conditions he may be deprived of food and drink for a long period of time. The journey out of the trenches is long, tedious and hazardous, and may greatly add to the patient's shock. It is, therefore, obvious that special training for proper treatment of such cases must be obtained and must be derived from practical experience at the front and cannot be replaced by theory."

The Carrel System.—The new faith, as taught by Carrel, whose weapon for wound disinfection has shown more weight than any other arm in offensive action, has led to the rewriting of some chapters on this subject of wound drainage. We know, for instance, that the sterilization of septic pockets is quite easily accomplished by the omission of the counter opening in the dependent part of the wound, and by following the Carrel ritual, which is familiar to you all and may be defined as: A combination of procedures, with surgical operation and mechanical cleansing, by which a chemical substance is used under specific conditions of contact, concentration, time and under bacteriological control. We have repeatedly demonstrated that in some of these intra-abdominal, rotten abscess cavities, whether of appendix or tubal origin, one can see the charted microbic curve progressively fall to the zero line, when the instillation tubes have been carefully placed and the technic of Carrel rigidly enforced. It should be emphasized right here that Carrel never intended his system of wound sterilization to take the place of early clean surgery or exteriorization of wounds, as Captain Wooler calls it, and the removal of all foreign material. Doctor Gibson has well said that while chemical sterilization has become a most valuable adjuvant, it must not be regarded a substitute for good surgery.

Gunshot Wounds of Abdomen.—The subjoined report from a well-directed ambulance somewhere in France [9] is interesting to us in this dis-

cussion, as both operators discourage the use of drainage in gunshot wounds of the abdomen. Of 64 abdominal wounds, mostly multiple, received in the reporter's ambulance, 22 died in a state of shock within a few hours, without operation; 20 others treated expectantly on account of the benign nature of the injuries recovered. Forty cases received operation with 20 recoveries and 20 deaths. It was claimed that the season of the year seemed to have a particular effect, as there was a mortality of 60 per cent. in the cold season, as compared with 40 per cent. in the warm season. Fifteen of the 40 cases had a single abdominal wound, 25 had at least two, and the others varied from 4 to 20 wounds. Multiple wounds gave a mortality of 68 per cent. as against 20 per cent. for single wounds. Operation was performed whenever the pulse was perceptible. The writers have entirely discontinued lavage of the peritoneum with ether, owing to the abrupt fall in pressure. Warm salt solution was used. Drainage of the abdomen was not encouraged as the authors claimed it was useless or even harmful, but occasionally the Douglas pouch was drained for from 24 to 48 hours.

Abuse of Drainage Tube.—Hathaway [10] condemns the drainage tube, and although his results are brilliant, his position will hardly be subscribed to without reservation by the members of this Section. He believes that if surgeons will take their courage in both hands and will not be frightened by a little infection, leaving it to be dealt with by the natural resistance of the tissues to infection, and will give up the use of drainage tubes, they will not only find their results very much better, but will find their outlook on surgery totally changed. All that is necessary is to put something into the tissues which will keep a "passage" open, but which does not leave an open "drain." If a passage is required to be kept open, Hathaway puts in a piece of soft folded rubber, for instance, in an appendix abscess. This allows pus to come away, but will not leave an open "drain" by which secondary infection of staphylococci, from the skin, or other organisms can gain entrance.

War surgery has taught what should be the two main principles of civil surgery: (1) Early and complete operation. (2) That secondary or mixed infection is worse than primary infection. While the tissues of the body can, if given a fair chance, deal with one infection only, if that infection becomes a mixed one by entrance of organisms from outside, then the last state is worse than the first. Applying his experience of modern war surgery Hathaway started sewing up ordinary staphylococcic abscesses of the subcutaneous tissues, after incision and wiping out with bipp, and found they healed by first intention.

Hathaway then went a step further. He saw a case of perforated gastric ulcer two hours after perforation, and operated within four hours. He sewed up the perforation, and, as it was near the pylorus and tended to close it, did a gastro-enterostomy. He mechanically cleansed the peritoneum of food, washed out with flavine, and sutured completely. The result was healing by first intention and an uninterrupted recovery, better than he had

experienced with the use of a drainage tube. Then he had to treat a bad compound fracture of tibia and fibula with a large external and contused wound, in a boy who had been run over by a motor lorry. He excised well clear of all damaged tissues, wiped out with bipp, and so mechanically cleansed and closed the whole wound by primary suture. The result was healing by first intention without a trace of suppuration.

The next step forward was in a case of gonococcal peritonitis. The peritoneum was infected and the abdominal cavity contained a turbid fluid; he removed one fallopian tube full of thick gonococcal pus, cleansed the peritoneum mechanically, washed out with flavine, and closed without drainage. The result was uninterrupted recovery and healing by first intention.

We quote freely from the report of Hathaway's series of cases on the abuse of the drainage tube, hoping it will provoke the fullest discussion.

I believe it is yet to be proved that the closing of a septic abdomen without drainage is an unqualifiedly rational procedure. No matter how thoroughly a peritoneal toilet may be made, there often lurk behind myriads of colonies of pathologic organisms, which may overwhelm the resistance, paralyze the arm of defense, and change what has seemed, at the operating table, a victory, into defeat.

Drainage Following the Pus Appendix.—Dr. John W. Keefe [11] in his excellent paper on Abdominal Drainage has asked the question: "Where shall we make our incision for removal of the appendix?" The right rectus incision undoubtedly offers a better abdominal exploration in cases of chronic appendicitis; however, the possibility of a post-operative hernia must be considered where drainage becomes necessary. It should be remembered that this incision presents other disadvantages, in that it is not always directly over the offending organ, and, as Doctor Kelly has pointed out, drainage thus may become difficult. After all, many things must influence the choice of incision, the location of the pain, and some definite conception of the pathology, based on the clinical picture, and the laboratory findings. The subject of drainage in a case of appendicitis can not be definitely decided until the abdomen is opened. In acute appendicitis when the question of drainage is always to be considered, the writer has almost invariably preferred the McBurney "gridiron" incision; recognizing with Doctor Keefe that it is least likely to be followed by a hernia, and through this incision adequate drainage can be obtained. We have never had the least trouble by sufficiently enlarging the incision, in exploring the pelvic basin, where this step seemed necessary. Again, should it be necessary to interrogate the gall-bladder or stomach, or to deal with these organs surgically, I am convinced that a second incision is the wiser course to pursue.

While we cannot subscribe to all that has been written by Dr. J. W. Long,[12] of North Carolina, it is interesting to record his experience in a series of 39 cases of acute appendicitis, some of them of the gangrenous type. He closed the abdomen in each of them, and his results were gratifying in 37 of the series.

Dr. Howard A. Kelly[13] writes: "An appendiceal abscess should never be disinfected and closed without drainage. When there has been much pus, a large opening ought to be left for free drainage; but before the drain is inserted the relations of the abscess must be studied, and pressure made upon it in various directions in order to ascertain that there is not some other cavity communicating with the primary one."

Most of us have followed the teaching of Dr. John B. Deaver, where the cul-de-sac is suspected of harboring pus, by introducing a catheter and aspirating with a syringe, during and after the operation.

Doctor Kelly definitely lays down essential points to be remembered:

"The drain is only a drain to a limited extent and for a short time; it acts chiefly as a protective pack.

"It is essential that the whole septic area should be drained.

"The drain must be loose in order that it may absorb rapidly. It must never be firmly packed.

"The drain must have exit through a large orifice.

"Whenever possible, the drain must be to an orifice in a dependent position. The drain must be watched, and as soon as it ceases to discharge it must be loosened or wholly withdrawn.

"In a small abscess it is sometimes best to leave the drain in for a week. Fatal infection has occurred from removing it too soon and thus breaking up protective adhesions."

Although Doctor Kelly's words were written thirteen years ago, I am convinced that this teaching may be safely followed to-day. Where there has been a general peritoneal infection, or in cases requiring temporary drainage, we have frequently seen the happiest results from a suprapubic or loin stab-wound drainage. Yet Deaver[14] reports two cases of obstruction of the bowel following adhesions along the tract of the pelvic drainage, and declares that in the future he will omit the pelvic drainage in cases with but little inodorous fluid. Hitzrot, of New York, reported to the writer personally, three other such cases in his service at the New York Hospital.

We prefer the split rubber tube, wrapped with gauze and covered with rubber dam, or the rubber dam and gauze wrapped or rolled cigarette fashion, judiciously placed at the bottom of the septic pit, or flanking definitely the seat of infection. When the drainage passes only to the fascia we have used the ordinary rubber band. The writer is indebted to Dr. Frank S. Mathews, of New York, for this simple yet efficient means of draining small pockets.

Whatever material is used, we should always remember the fact pointed out by Coffey and emphasized by Keefe, that a drain is efficacious only in proportion to the area of a transverse section at the point of obstruction. A point we wish to emphasize here is the imperative importance of the surgeon, or a skilled and trustworthy assistant, following up the mechanism of all abdominal drains. The writer, more than once, has seen a tragedy due

to a cigarette drain blocking the passage of septic material, with the inevitable retention, overwhelming toxæmia and death.

Remember, in using the drainage tube as the central core of the cigarette, or as an individual drain, care must be exercised in the selection of a perfectly pliable yet non-collapsible pure rubber. We have known of perforation of the intestine, due to pressure of an unyielding white hose pipe tube of the fishtail cut.

Many of us who served our internship in the early nineties can bear testimony to the faithful performance of the large glass tube, aspirating syringe and soft catheter in the pus abdomen.[15] The writer published several years ago a series of seven gunshot and stab wounds of the abdomen, each with visceral perforation; the glass tube was used in each of these cases with recovery, without hernia or secondary infection. Notwithstanding the large glass tube has been relegated to the junk of seldom used armamentaria, we think that there is still a place for it in selected cases.

Rutherford Morrison[16] regards the toughened glass tube of Keith the best form of drainage in pelvic sepsis.

Howard A. Kelly[17] says the drainage ought never to be omitted in the pelvic abscess and is best carried out by means of rubber tubes a centimetre in diameter.

It was the writer's privilege, many years ago as an interne in Presbyterian Hospital, New York, to assist in the operation and have the after care of a case of Dr. Charles K. Briddon's:[18] A neglected pyosalpinx, with firm old adhesions. In the course of extirpation there was a complete transverse rupture of the rectum, necessitating the formation of a temporary artificial anus. A secondary operation was performed for reconstruction of the rectum, from which the patient recovered with complete control of function.

In this classical case, as in all of the graver forms of pelvic suppuration, Doctor Briddon used the intraperitoneal iodoform tampon. To facilitate the removal of the gauze, it was the custom of this operator to pass one or more glass tubes down to the bottom of the cavity and to pack loosely around these a liberal amount of gauze.

With regard to these graver forms of pyosalpinx we will all accept without reserve the teaching of that great English gynæcologist, Lawson Tait. Whether we drain or not, certainly his words ring as true to-day as they did thirty years ago. In an address delivered to the French Surgical Congress in 1891, Tait said:

"I am quite certain now that in the hands of a competent operator there are no adhesions of the uterine appendages which cannot be overcome, and no case ought to be left unfinished. Incomplete operations are the opprobrium of abdominal surgery, and operators ought to be more discredited by them than by anything else."

Dr. J. Y. Brown,[19] of St. Louis, in a recent essay remarkable for its philosophic grasp, is of the opinion that the outcome of these pus tube cases

depends largely on the proper application of the drain. After the enucleation which is usually extensive, the cul-de-sac is left denuded.

Joseph Price long ago emphasized the value of the coffer dam, and Coffey, of Oregon, later elaborated on the technic of applying this drain. After the removal of the diseased tubes and the completion of the pelvic toilet, with the patient in the Trendelenberg position, the intestines are lifted from the cul-de-sac. Gauze tape about 36 inches in length is now placed from right to left, filling the cul-de-sac and covering all raw areas. The end of the gauze is then brought out at the lower angle of the wound and slipped through a very thin rubber tube. Brown is confident that this type of drain will prevent post-operative ileus. He pays a generous and well-deserved tribute to the genius of the late Joseph Price when he says: "To him more than to any one man in America, is due the credit of having placed pelvic surgery on a sound and substantial basis."

Drainage in Tuberculous Peritonitis.—We have been definitely taught, and the teaching has been strengthened by experience, that the peritoneal cavity, when the seat of an unmixed tuberculous infection, should never be drained. The explanation has been found in an etiologic factor, which has been clearly explained by Dr. W. J. Mayo,[20] who has called tuberculous peritonitis a symptom and not a primary disease, arising secondarily to a local lesion, usually in the fallopian tubes or the intestinal tract, or from retroperitoneal glands. The abdominal ostia of the fallopian tubes in tuberculosis are usually open, while in gonorrhœa, Murphy has taught, they are nearly always closed. The infective tuberculous material from the tubes passes with freedom into the peritoneal cavity, and, as pointed out by Doctor Mayo, the resulting reaction with accumulation of ascitic fluid we speak of as tuberculous peritonitis. The real explanation of the exceptional recoveries of these patients following abdominal section is, that the fimbriated mouths are closed by adhesions, or by becoming attached to some neighboring part of the peritoneum. But the tragedy comes too often following incision and drainage; the mixed infection, the fecal fistula, the hectic with its "picket fence temperature," and the fatal exhaustion. Doctor Mayo therefore concludes:

"1. Those afflicted with tuberculosis do not die of the disease, but from the associated sepsis. 2. Drainage of the abdomen should never be used in tuberculosis of the peritoneum. 3. Pure products of tuberculosis in the pelvis should be removed, wherever possible, by clean, careful operation."

The writer has only attempted to touch the fringe of some of the important phases of this drainage problem.

We do not wish to be understood as making a plea for any particular form of drainage in a purulent peritonitis, but humbly present a simple chronicle of facts, opinions and observations from the hospital wards.

This whole subject of drainage presents certain definite scientific principles which must be applied with judgment to each individual case. Doctor Draper at one time said, "Mere technic is easy, the modern surgeon must

be more than a mere craftsman." Get hold of the principles, therefore, and do not follow with dogmatic blindness an unvarying ritual in every pus abdomen which you may lead to the operating table.

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FRACTURES OF THE UPPER END OF THE HUMERUS

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The treatment of fractures of the upper end of the humerus which involve the shoulder joint have been various, but the results have been, in the great majority of cases, remarkably alike; that is, unsatisfactory both to the patient and to the surgeon; long periods of disability with restriction of motion—many of them presenting a permanent disability out of all proportion to the apparent pathology.

Forward and backward motions at the joint have been usually recovered in greater part, but the restriction to motion following fracture of this type is usually apparent in abduction movements, especially after the arm has swung above the horizontal plane, and external rotation is restricted and has been recovered only after long periods of time or not at all. Many of the patients who have suffered from this type of fracture have to a certain extent only themselves to blame, as they lay down very early on account of the pain produced by passive and active motion at the shoulder joint, and once they are able to get the hand to the head they become reconciled to the result and never make the extra effort necessary to the full recovery of abduction and rotation movements at the joint. These fractures have been treated up to the present time with remarkably little intelligence and apparently with remarkably little understanding of the physiological anatomy of the shoulder joint and an equally slight understanding of the pathologically mechanical factors which have entered into the problem of restoration of function once there is a solution of continuity of the bony structure with injury to the joint surfaces.

These cases are immediately (in the great majority) locked up with a shoulder cap, oftentimes the entire arm and forearm swathed in bandages; the forearm carried across the chest and slung from the neck with a sling, this position perforce putting the lower end of the fracture if not impacted into internal rotation—if impacted, putting the whole length of the humerus into internal rotation. If the shaft of the humerus is also involved coaptation splints are added, and oftentimes a right-angle splint at the elbow is included. These are left on for a variable length of time, but it has been my experience that it is more often four or five weeks than less, and I have seen some cases where splints have been left on for a longer period of time, before motion was instituted. Under this treatment it is a long series of months before a workable arm is obtained, and the wonder is not that it is so long a time before recovery of a useful arm, but that they recover the use of the arm at all.

Nearly all of these cases for months and even years afterward, and in fact for the remainder of their lives, show certain pretty definite restriction of motion, especially in abduction and external rotation. They gain the motion

which they have at the expense of a tremendous amount of pain when motion is begun and for a long time afterward, in which subdeltoid bursitis many times plays a part and brachial neuritis is a close second, but of which the major part is played, in our opinion, by certain definite inflammatory roughening of the joint surfaces themselves—traumatic arthritis.

The second type of treatment, which shows more intelligence than the preceding because based upon a certain amount of definite anatomical knowledge, has been used principally in those cases where the head of the bone has been split off and abducted, leaving the shaft so clearly out of continuity that it was obviously impossible to bring the two surfaces together in the ordinary position of treatment, and here the arm with the lower end of the fragment (the shaft) has been abducted and manipulated with the hope of entangling the broken-off head and so bringing it down into a reasonable alignment with the shaft, or of treating it in this position of abduction after the two surfaces have been coapted as nearly as seemed possible. Lately, in a few cases, we have had reports of abduction with extension, a logical method, but this in the main has been used in those cases of military fracture that have resulted from the present war.

In all these cases the period of time of treatment has been much the same, but I think that on the whole the results have shown some change for the better. Some few later-day writers have advanced the idea of treatment in abduction and external rotation, but in every case where I have studied their charts, illustrations or photographs, their treatment has shown internal rotation and not external rotation—most of these cases being treated on ambulant splints, the arm in abduction, the forearm on the horizontal plane in front of the transverse plane of the body, which means internal rotation of the humerus always. So far as I have seen there is no ambulant splint of any type which permits abduction and at the same time external rotation without being absolutely or practically impossible of application. A patient does not wish to go about with his arm in the air like the Statue of Liberty.

Fracture of the upper end of the humerus is an extremely common kind of fracture, and is usually the result of a fall by middle-aged or elderly people with the arm in abduction and internal rotation. There are several types of these fractures, and it is necessary to their understanding that one should have a clear conception of the anatomy of the shoulder joint.

The joint itself, consisting of the shallow cup of the glenoid and the head of the humerus, together with its capsule, is a loosely fitting joint, the head of the humerus being held into the glenoid socket by the various muscles which surround it, and not by the capsule. The supraspinatus above, the infraspinatus and teres minor posteriorly, and anteriorly the subscapularis, by their insertions into the greater and lesser tuberosities serve to hold the head of the humerus against the glenoid. At practically right angles to these the tendon of the long head of the triceps behind and the biceps and coracobrachialis in front cross the capsule and strengthen it. Over all is the very strong deltoid muscle. The inferior surface of the capsule is probably the

only part of the true capsule which is tense at any time, and this is true only in abduction. The head of the humerus may be for all practical purposes considered as a ball surrounded by muscles whose purpose it is to rotate it outward and inward and the supraspinatus above to tilt it upward so that the mean line of the deltoid (the deltoid pull) may become efficient in abducting the arm which it cannot do while the arm is against the side. (See Figs. 1 and 2.)

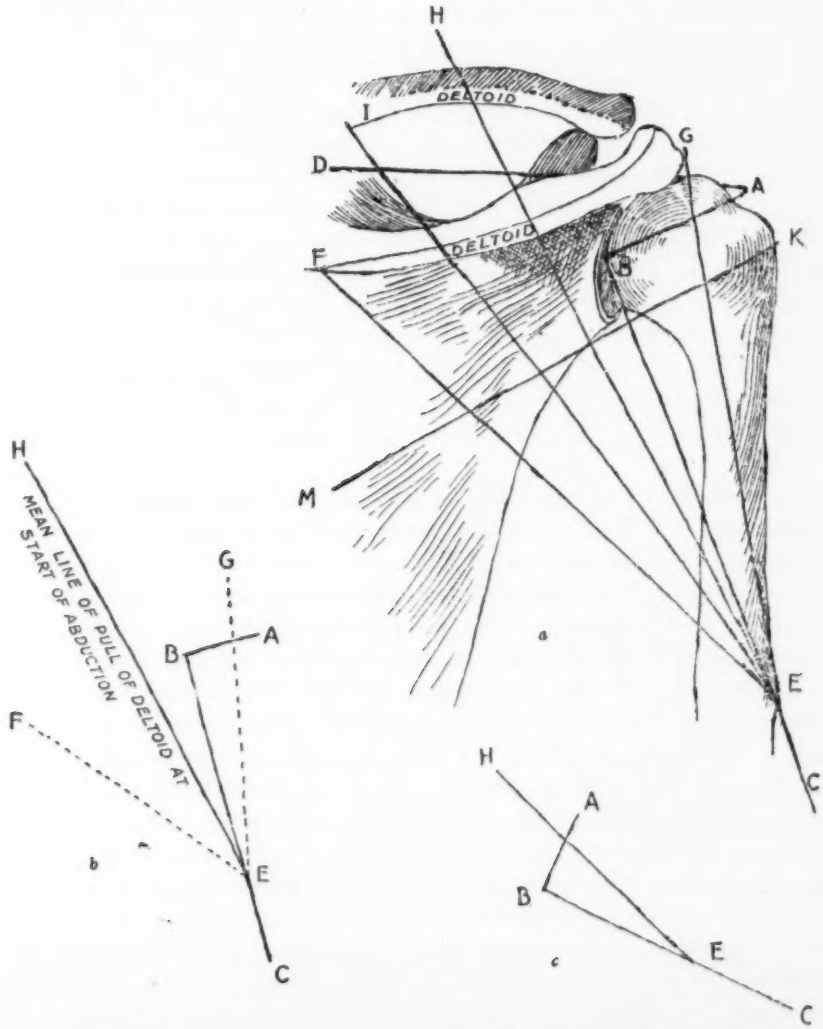

FIG. 1.—Showing the lines of pull of the fibres of the deltoid providing these fibres acted together, *H E* being approximately the line of such pull, showing that in this case it could not act on the lever *A B C* to abduct it. Assuming that the acromion portion of the deltoid acted as a separate muscle or as a separate contraction, then it could (consider the line *G E* and its effect acting at *E* on the long arm of the lever *A B C*) aid in starting the humerus upward in abduction, but should its fibres act simultaneously the line of pull would be inside the fulcrum *B* (*a*) and provided it was in contraction it would act in opposition to the line of pull to the supraspinatus, *D A*. In order to act on the long arm of the lever the line *H E* must fall outside the point *B* (fulcrum), and this is possible only after the long arm of the lever (the humerus) has been partially abducted (*b*), which is done up to this point by the supraspinatus *D A* acting at *A* on the short arm of the lever *A B C*. *A*, the power, *B*, the fulcrum, and *C*, the weight of the arm to be abducted. *K M* shows the line of pull of the short rotators causing external rotation. Especially pronounced, once there is a fracture of the surgical neck, putting out of commission the opposition of the pectoralis major and latissimus dorsi and teres major muscles.

The deltoid has nothing to do with abduction until after the supraspinatus has carried the humerus outward to a point sufficiently great so that the deltoid can come into play. What happens when these patients fall with the arm in abduction and how do we account for such a large number of fractures of this type? It is easy to say direct violence or excessive muscular action, but it is a pretty weak solution. Watch the normal abduction of the arm, standing behind the model.

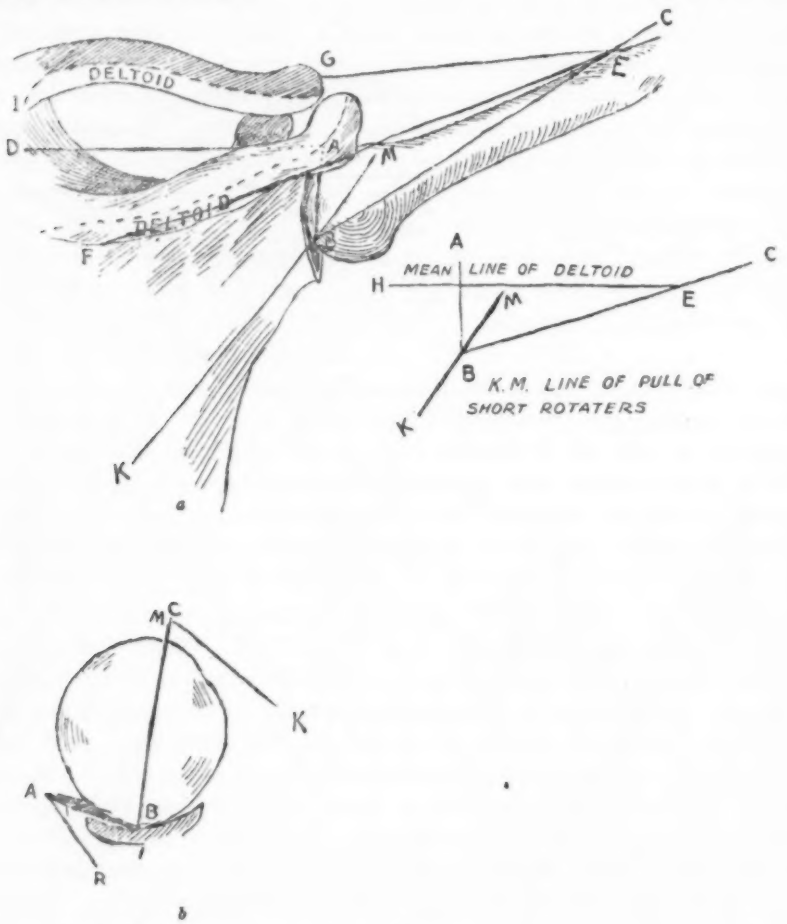

FIG. 2.—Mechanics of the second stage of normal abductions and of external rotation. This shows the lines of pull of the deltoid when the arm is partially abducted, *G E*, *F E* and *I E*. The line of pull of the supraspinatus, *D A*, acting on the short arm of the lever *A B C*, while the deltoid acts on the long arm of the same lever, its power being applied to *E*, a point between the weight *C* and the fulcrum *B*. Note also that both lines of pull, deltoid and supraspinatus, are above the fulcrum *B*, and unless there is another force applied the fulcrum of the lever would be unstable and render worthless any amount of power applied. That force (*K M*), the line of pull of the infraspinatus and teres minor behind and of the subscapularis in front, is supplied by these three short rotators, without which the head of the humerus would slip upward, answering the pull of the supraspinatus and deltoid. Note that the line of pull of the short rotators passes through the fulcrum *B*; therefore it acts merely as a tractor and exerts no force either on the long or short arm of the lever, consequently offering no impediment to the abduction, while at the same time rendering such action possible by keeping the fulcrum firmly in place. When the head is broken, *K M* and *D A* of Figs. 1 and 2 show how the upper fragment would be abducted and rotated outward. An entirely different leverage is formed, and the insertion of the infraspinatus and teres minor being on the long arm of this new lever would outweigh any pull of the subscapularis which could act on the short arm to oppose it and therefore the head of the bone would rotate outward (*b*). (*a*, *D A*, the pull of the supraspinatus) acting normally would simply tend to abduct the upper fragment.

With the arm extended fully and the hand in pronation (which means that the humerus is in internal rotation—not to its full limit but to a good degree in internal rotation) when the arm reaches a certain point in abduction, varying in different persons but always well above the horizontal plane, no further abduction of the arm is possible in this position; but if the humerus is now rotated outward from its position of internal rotation into external rotation, the arm (humerus) is freed immediately from its previous restriction and can be further abducted so as to approximate the arm to the side of the head. This movement is readily understood from a study of the normal anatomy of the humerus and the acromion process of the scapula. The greater tuberosity of the humerus in the position of internal rotation impinges on the tip of the acromion process of the scapula, between which and the greater tuberosity there is very little clearance even up to this point, and at this point the greater tuberosity is brought against the tip of the acromion, motion is arrested and cannot be carried in abduction beyond this point (Fig. 2). The actions of the short rotators now come into play; the humerus is rotated outward by the infraspinatus and teres minor, which brings the normal depression that exists in the head of the humerus between the greater tuberosity and the lesser tuberosity into line with the tip of the acromion process and this movement permits exactly enough clearance between the bones so that the humerus is permitted to continue the arc of abduction.

Should a patient fall with his arm in abduction and external rotation, nothing would happen to him save that his arm would be forcibly extended above his head, the arm resting alongside his head, and one could not imagine a force other than a sharp edge which would produce a fracture at the neck of the humerus. But one never falls that way; instinctively he throws out his arm in abduction, his hand in pronation, and as the hand strikes the floor first a terrific impetus (the impetus imparted by the entire weight of the victim) is given to the abducting arm. The greater tuberosity goes smash up against the tip of the acromion process (see Fig. 2), which is a strong bony structure constructed exactly like the arch of a bridge. One of three things happens where fracture occurs: either the tip of the acromion must break, which it seldom does, or the tuberosity of the humerus is smashed off together with the insertions of the supraspinatus, the infraspinatus and teres minor; or the tuberosity resisting the strain holds and the entire weight of the man's body falls upon the neck of the humerus and this gives way. If all three hold then a dislocation is all that results and this is common in youth. In older persons the bony structure is changed and fracture is the rule.

It is surprising how often the greater tuberosity alone gives way, thus distributing the pressure and saving the neck of the humerus, the fracture resulting simply in a split-off greater tuberosity (Figs. 3 and 4). If the force is sufficient and the break free, the short rotators, the infraspinatus and teres minor, aided by the supraspinatus to a lesser extent, may

pull the broken tuberosity entirely out of place, or it is pried out of place by the tip of the acromion process and it may even disappear behind the head of the humerus (see Fig. 4). More often, however, it is not entirely displaced. In many of this type the fracture of the greater tuberosity is minor in character and not sufficient in extent to free the head of the bone, the force continues along the intact shaft, the tip of the acromion acts still as a prying force to externally rotate the bone, and this force continuing dislocates the humerus through the only part of the capsule unprotected by muscles—the inferior portion, and a subcoracoid dislocation is added to the first trauma.

In the second variety the surgical neck of the bone parts, the head and neck oftentimes being tipped upward, abducted by the action of the supraspinatus and always rotated outward by the action of the infraspinatus and teres minor acting from behind aided by the prying force of the tip of acromion. Sometimes when the head of the bone is not rotated and abducted impaction follows as the last stage of the trauma. All these cases present the common complication of torn ligamentous structure, traumatized tendons and a joint also traumatized and usually filled with blood and effusion, and in those cases where the bony lesion is slight and deformity little or none this is the really important pathological condition which must be considered in the treatment of these cases of fracture of the upper end of the humerus.

Should displacement be associated as it is many times, then measures must be taken first to reduce the displacement, and once this is accomplished the mechanical problem is exactly the same as in those cases which clinically and by means of the X-ray have presented little or no deformity, *i.e.*, treatment of the injury to the joint itself rather than treatment of the broken bony structure.

The break itself, whether it be of the greater tuberosity of the surgical neck or whether or not complicated by an oblique fracture of the shaft of the bone in addition to the break above, presents identically the same problems, and the results are good or bad according as one recognizes that it is not the fracture alone which must be treated but a traumatized joint structure, and that the disability resulting from improperly locking up a traumatized joint for long periods of time is just as great in those cases showing by the X-ray a splitting off of the greater tuberosity without displacement as it is in the apparently much more serious type with fracture across the neck of the bone with or without displacement or impaction. Better results will be obtained if treated along anatomical lines where there is no impaction, but I have come to believe that in comparatively few cases is there real impaction in these cases of shoulder fracture.

If it takes place before the split-off head rotates externally, it is a matter of small importance; if it takes place after the head has rotated externally and is not broken up, then external rotation afterward will always be lost to a certain degree; but fortunately it takes place, if at all, before rotation of the head, and where rotation of the head can be demonstrated it is pretty

safe to conclude that there is no impaction. In these cases it is necessary to take into consideration the insertion of some of the other muscles.

The pectoralis major is inserted into the outer lip of the bicipital groove of the humerus and the latissimus dorsi and teres major are inserted into the inner lip of the bicipital groove. They are all below the site of the usual fracture of the neck and where there is no impaction they tend to pull the lower fragment inward and also rotate it inward as well.

The long head of the triceps behind and the tendons of the biceps and coracobrachialis in front tend to pull up the lower fragment, so that we have an upper fragment, the head of the humerus, broken off and if displaced tilted upward and externally rotated, a lower fragment pulled inward and always if not impacted rotated inward. Every case of fracture of this kind should have a stereoscopic X-ray taken if you wish to demonstrate the external rotation. The demonstration of rotation in any long bone from the ordinary X-ray plate is an impossibility and an absurdity.

The case represented by Fig. 7, a fracture of the surgical neck compliplicated by an oblique fracture of the shaft of the bone, demonstrated this external rotation beautifully when pictured stereoscopically. Although the lower fracture runs obliquely low down on the shaft of the bone, the line of fracture anteriorly passed internal to the insertion of the latissimus dorsi and pectoralis major, and this fragment, which is really in this case a third fragment of bone, moved with the upper fragment or head and showed the same external rotation which is shown by a fracture across the neck alone. The upper fragment, and in this case also the inner fragment since these two were more or less entangled and moved as one, demonstrated the external rotation produced by the infraspinatus and teres minor; while the lower fragment which is in this case also the outer fragment (a rather unusual condition) is internally rotated by the action of the latissimus dorsi, teres major and pectoralis major.

The shaft of the bone entangled with the upper fragment or head (in this case the internal fragment) is also pulled slightly forward because the coracobrachialis is intact and is attached to this fragment. That it does not distort it more pronouncedly is probably due to the attachment of some of the upper fibres of the internal head of the triceps which serve to prevent further displacement. This is the type of case where damage to the musculospiral is much to be feared. It is not absolutely necessary to have a stereoscopic plate made of all of these fracture cases, because it is safe to assume that this rotation externally is exactly what has happened in every case.

Should we bring these bony structures together by manipulation in this position, the upper externally rotated and the lower internally rotated, we should hardly expect a good result, because external rotation would be lost while internal rotation would be increased. This is exactly what happens in these cases treated by the usual method, which, no matter what type of dressing is used, treats them in internal rotation. The abduction ambulant splints are no better from the standpoint of overcoming this external rotation,

because all that I have seen treat the arm in abduction to be sure which is an advantage—but they all place the forearm forward of the side plane of the body in a horizontal position and therefore they must of necessity result in internal rotation of the lower fragment.

A glance at Leyva's aëroplane splint will show this feature. Remains only an ambulant splint which, while permitting moving about, holds the arm in abduction and external rotation, the arm in the air, and a more uncomfortable position could not be imagined. Unless very carefully applied and carefully watched it might do more harm than good. It is entirely impractical.

These fractures of the head and neck of the humerus divide themselves pretty closely into three more or less distinct types. In the majority of cases only one type exists in any one case, but all may coexist.

CLASSIFICATION OF FRACTURES OF THE UPPER END OF THE HUMERUS

TYPE I.—Fracture of greater tuberosity without displacement (Figs. 3, 10, and 15). Subdivision A—with displacement of the fragments (Fig. 4). Both types may be complicated by subcoracoid dislocation. The shaft and neck are intact.

TYPE II.—Fracture of the neck of the humerus without displacement (Fig. 5). Subdivision A—with displacement of fragments, the head, however, remains in the glenoid (Fig. 6). Subdivision B—displacement of the head from its relation with the shaft. The head is also dislocated out of the glenoid.

TYPE III.—Fracture of the neck of the humerus with complicating fracture of the shaft of the bone (Figs. 7 and 8).

Type I. Fracture of Greater Tuberosity.—This is a very common type. There is not much displacement, and what there is, is easily overcome by a few days' treatment in external rotation. This type is well illustrated by referring to Figs. 3 and 10.

Subdivision A of Type I.—Fracture of the greater tuberosity is more extensive in degree, the entire greater tuberosity being split off and displaced backward (Fig. 4). Many of these cases can be co-apted by external rotation in abduction. Operation is required upon those cases in which this manœuvre fails and consists in tacking the tuberosity back into its place. Type I and its subdivision is frequently complicated by dislocation of the humerus—the force producing the injury to the tuberosity continuing through the intact shaft, forcing the arm into dislocation, the neck resisting the breaking force. In this type where operation is not required a few days, four or five, of extension, after reduction of the dislocation if present and immediate passive motion every day after the fifth. After the ninth or tenth day active motion. These cases should recover quickly with full range of motion. Some pain is likely to persist for a longer or shorter period of time, and is often due to subdeltoid bursitis.

Type II (*Fig.* 5).—The greater tuberosity resists the impact of the acromion. The force is transmitted to the neck of the humerus which gives

FIG. 3.—Type I case. Note how closely this case compares with Fig. 10.

FIG. 4.—Type I. subdivision *A*. This was an operative case, but general conditions prevented treatment demanded.

FIG. 5.—Type II: very little displacement.

FIG. 6.—Type II, subdivision *A*.

FIG. 7—Shows Type III case. Fracture of neck of bone which shows badly in print. Also oblique fracture of shaft complicating the really important fracture at the neck. Shows overriding of oblique fracture. See Fig. 8.

FIG. 8.—X-ray of Type III case, taken on twenty-fifth day. Shows what was accomplished by traction and abduction with external rotation. Compare with Fig. 7 taken on day of injury.

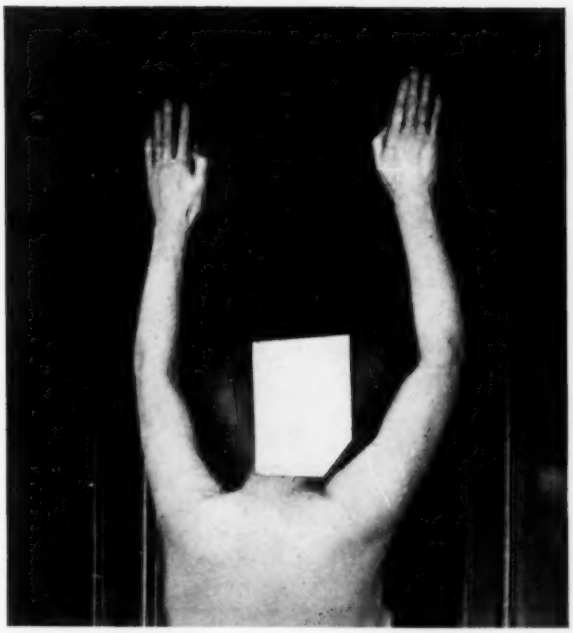

FIG. 9.—Showing motion obtained in case whose X-ray is shown in Fig. 3 on seventeenth day, the day of discharge. Some pain persisted afterward, but gradually ceased. Motion remained satisfactory. Slight degree of subdeltoid bursitis can be observed.

FIG. 10.—Type I case, showing simple fracture of greater tuberosity involving insertion of supraspinatus and teres minor. This case was treated by three weeks of restriction. The result is shown in Fig. 11, taken two and one-half years later, and shows the definite and permanent restriction in abduction which often follows this treatment even in these mild cases. Compare Fig. 10 with Fig. 3, which is almost identical, and compare Fig. 11 with Fig. 9, which shows the arc of abduction on the seventeenth day.

way almost transversely, many times with very little displacement and sometimes with impaction.

Subdivision A of Type II (*Fig.* 6) shows a very much displaced head, the head being drawn up by the action of the supraspinatus and externally rotated by the action of the infraspinatus and teres minor. The head of the bone is not dislocated in these two types. The neck of the bone has given way before dislocation, thus distributing the pressure, but the upper fragment is always rotated outward and many times abducted. Abduction and external rotation with block and tackle usually reduces this type easily and the abduction and external rotation with extension, eight to ten pounds, is the treatment in both forms of this type. Passive motion should be begun on the fifth day in cases without displacement, and thereafter treated like cases of Type I. Subdivision A of Type II should have passive motion not later than ten days after injury and oftentimes before this, and subsequent treatment is as in the other types.

There is a Subdivision B of Type II, fortunately rare, the head of the bone entirely separated from the shaft and also dislocated from the glenoid. The dislocation is subcoracoid in type because the dislocation is the first thing to occur, and the fracture of the neck is secondary to the dislocation, from the continuance of the leverage along an intact shaft, the head of which has lodged below the coracoid process of the scapula and is held more or less rigidly in its new position. This fracture is operative and requires oftentimes section of the tense subscapularis muscle before the head can be replaced in the glenoid. This type is of no special importance so far as the purposes of this paper are concerned. After operation the treatment would be much the same as that for the other types, but somewhat less rapid.

Type III (*Figs. 7 and* 8) is also fortunately rare and is in reality a different complex entirely, usually resulting from a more serious trauma than a fall with arm in extension. I have usually found it where the patient has fallen down stairs and a twist of the bone has been added to the other forces, causing a spiral fracture of the shaft complicating a fracture of the surgical neck and sometimes in addition a split-off greater tuberosity.

Treatment is the same as for the other types except that extension in external rotation and abduction is continued until twelfth to the fourteenth day. Coaptation splints are required for the oblique fracture of the shaft and great care must be exercised on instituting passive motion because of the broken shaft. The amount of weight necessary in these cases varies. It must be just enough to overcome the tendency to override and no more. Traction is discontinued after the arm is brought down to the side, as can be done by the twelfth or fourteenth day. Passive motion should be begun not later than fourteen days and active motion after sixteen days if care is exercised with the broken shaft. I have considered it absolutely safe, and have found it so in practice, to begin active movement by this time.

In these cases where recovery is slower than in Types I and II, most of the patients being elderly people (as is unfortunately true of all the other

types), I have found it advantageous in some cases, in order to prevent stiffening at the joint, to return the arm to the abducted position overnight every second or third night, but without extension, and to keep this up until active motion in abduction has reached a satisfactory point. Many of these cases present other complications which must be recognized. The treatment must not be blamed for failure to recover a useful arm if the musculospiral nerve is injured with resulting wrist-drop. This must be recognized from the start. The posterior circumflex nerve may be injured with resulting deltoid paralysis. Some of these cases show a deltoid which refuses to act at first, but which recovers rapidly after motion is instituted, showing that the nerve was not seriously involved.

We must also recognize that injury to the entire brachial plexus may also occur in these cases and also that in certain cases, as advanced by Codman, of Boston, the tendon of the supraspinatus itself may be caught between the acromion and the tuberosity and divided. This is recognized by absolute inability even to start the arc of abduction (Fig. 1). Later on we have subdeltoid bursitis and brachial neuritis and the results of a traumatic arthritis to contend against.

The treatment of these cases, roughly outlined above, is an interesting study and is an extremely simple proposition except in those cases where the shaft and the head cannot be coapted or where the head is also dislocated and separated from the shaft. The first procedure where there is deformity is a block and tackle to the lower arm in abduction, with the forearm flexed to release the tension of the biceps. The pull must be strong and steady, and while this is continued the arm is rotated into external rotation to correspond to the externally rotated upper fragment.

By means of manipulation the head and shaft can be coapted in nearly all cases, and where the greater tuberosity has been separated widely one will be astonished to find how closely it becomes approximated to its normal position. The arm is secured to the retention apparatus in this position, there being only one simple or efficient method for the treatment of this type of fracture in abduction and external rotation and that is treatment in bed, all advocates of ambulant apparatus to the contrary notwithstanding. With treatment in bed for some days varying with the type of fracture to be treated the position of external rotation is the simplest thing in the world and the patient is more comfortable than with any other method.

Some years ago when I first instituted this treatment I did so in fear and trembling. I had imagined a great amount of discomfort. I was agreeably surprised to find that I need not have worried. They are as comfortable as in any position. The splints which I employ are shown in Fig. 14, and the usual one used marked "A" is simply a right-angled wooden splint well padded. The arm is laid upon the longer side and attached to it not too snugly, the inner body end of this arm extending almost to the midline of the body. A pillow under the opposite shoulder prevents any discomfort to the patient. The forearm rests on the shorter arm of the right angle, extending

toward the head of the bed above the head and is held lightly with one or two cheese-cloth strips leaving the hand and wrist free for motion. Sometimes the wrist is tied to the head of the bed, but the hand is left free for use. A cord is suspended from the head board for the use of this hand.

In many of these cases, especially of Type I and sometimes of Type II, there is no necessity for splinting in the ordinary sense of the word at all. There is little tendency to displacement where the surgical neck is alone involved or in those cases of Type I presenting a simple fracture of the tuberosity where there is no displacement. Simply placing the arm in abduction and external rotation is all that is required for these cases. The important part of the treatment is the traction of seven to ten pounds for the first four or five days, the arm in abduction and external rotation resting simply on a firm pillow splint. Traction is secured by means of plaster strips along the arm extending high up to the fracture or by means of a sling about the arm, forearm and splint at the elbow.

This treatment accomplishes its object in several ways:

First, it is the necessary treatment in all cases of arthritis, as has been so ably advocated by Murphy of Chicago. And every case of this kind, no matter how simple it may seem, is a case of arthritis. The joint is always involved, is always traumatized and nearly always full of effusion and blood. Extension puts the joint at rest, prevents the traction of the various muscles and relieves the tension inside the capsule. The treatment accomplishes another equally important thing. It starts treatment in abduction above a right angle, and therefore it is a much simpler matter to get the arm back into this position later when active and passive motions are begun. Some of these cases presenting apparently slight damage, show later an excessive amount of callous formation which if allowed to calcify absolutely prevents the tuberosity from sliding under the tip of the acromion, the callus impinging on the acromion after the arm has swung beyond a right angle. Full abduction in these cases becomes an impossibility and this loss of motion is permanent (see Fig. 15).

With the bones in the position of abduction and external rotation and by passive motion early this tendency if present is overcome, the soft callus is planed down as it were and rarely becomes of serious importance. In the minor cases the arm is gently moved in passive motion after the fourth or fifth day and traction is discontinued on this day, the arm brought to the side, gently rotated inward, and the forearm supported by a sling, the arm being held to the side with a wide swathe. If we could be sure of coöperation and care by the patient the swathe could be discarded in these cases. It appeared to me at first that extension was hardly necessary in these mild cases—that passive motion early would accomplish the purpose equally well, but I have come to believe that the extension even in these mild cases is equally important with early motion, and that the more serious types apparently recover under this treatment almost as rapidly as the others. In other

words, it is the injury to the joint and not the fracture; and the simple types have injured the joint structure sometimes quite as much as the others.

Sometimes I have thought that in the pre-X-ray days, when this lesser type of injury to the shoulder was probably not recognized as a fracture, and therefore not treated as one, the recovery was most likely quicker than it has been since we have had the X-ray to aid us. Since we have had the X-ray and under the usual treatment these cases have not recovered the functional use of the arm much more quickly than the more seriously injured and nearly all of them have presented permanent impairment of motion months and even years afterward. Fig. 10 represents a case of this kind—a Type I injury which was treated by a good surgeon. Swathe and sling for three weeks only—and I have seen many treated by restriction for much longer periods—yet this was quite long enough to do the damage. Fig. 11 shows this case and the permanent restriction of motion two and one-half years after. He has never recovered full abduction. Compare Fig. 10 with Fig. 3 and you will see the remarkable similarity of the pathological process. Fig. 9 represents the amount of active motion which was obtained in the case represented by Fig. 3 (a Type I case) in seventeen days by our method of treatment. This case was discharged on the seventeenth day. There has been some pain on active motion which will gradually wear away, but there is little restriction to motion itself.

I believe the extension is the important factor at first, and that at any rate it lessens pain in motion later. Active motion (slight at first) in abduction after the seventh day. Rotation movements are usually left to the last and are carried out gently but actively after nine or ten days.

Some of these cases will show limitation of motion due to a subdeltoid bursitis for some time, and pain to a certain degree is to be expected for a time (Fig. 9).

The treatment by traction and abduction is to my thinking the best preventive for this condition, and I have found this complication less frequently since I have used it. In the more serious cases the treatment is very much the same. (Figs. 5, 6 and 7 represent these types.)

In case represented by Fig. 5—Type II case—passive motion was begun on the sixth day, but not the full range, and gradually increased in extent; active motion after the seventh day, but restricted at first. Final result of motion is shown on thirtieth day by Fig. 12. Case represented by Fig. 6 —Type II case—Subdivision A, presented difficulties in reduction, but once reduced the treatment was as simple as the others, motion being begun somewhat later, and later than I now begin it even in this type. Passive motion on twelfth day and active motion a few days later. Fig. 13 shows the result in this case and represents the degree of motion attained on the thirty-second day.

Fig. 7 represents a much more serious injury—Type III—the break through the surgical neck being complicated by an oblique fracture of the shaft of the bone with overriding. This case was treated on the right-angled

FIG. 11.—Two and one-half years after injury under old treatment. Permanent restriction in abduction and external rotation.

FIG. 12.—Shows motion obtained on thirtieth day. Pain in this case was considerable. Worse at night and persisted for some months, but motion was satisfactory from the first. X-ray of case shown in Fig. 5.

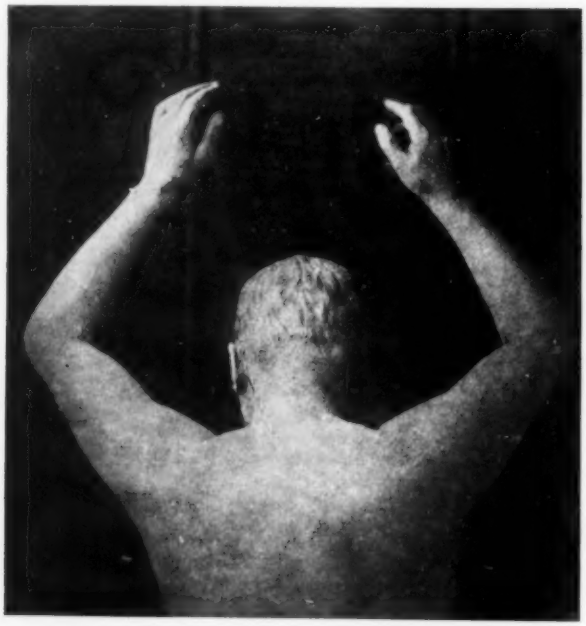

FIG. 13.—Type II, subdivision A, showing motion obtained in Fig. 6 on thirty-second day. Equally good motion shown earlier than this, but photograph is thirty-second day. Pain not pronounced in this case.

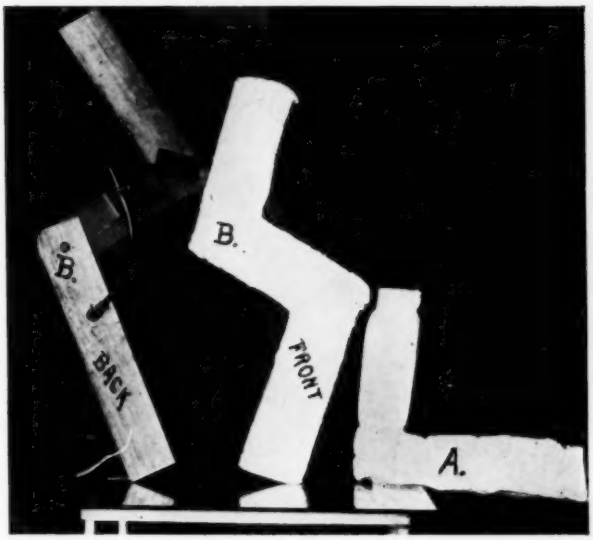

FIG. 14.—Shows splints which we use and call our own. *A* is splint used in nearly every case. *B* shows back and front of special type which we have used in special cases, but it possesses no advantages over the simple right-angle boards.

FIG. 15.—Note excessive callus after Type I case. This callus impinges on the tip of the acromion process, and makes abduction above a right angle an impossibility in this case. This should have been prevented.

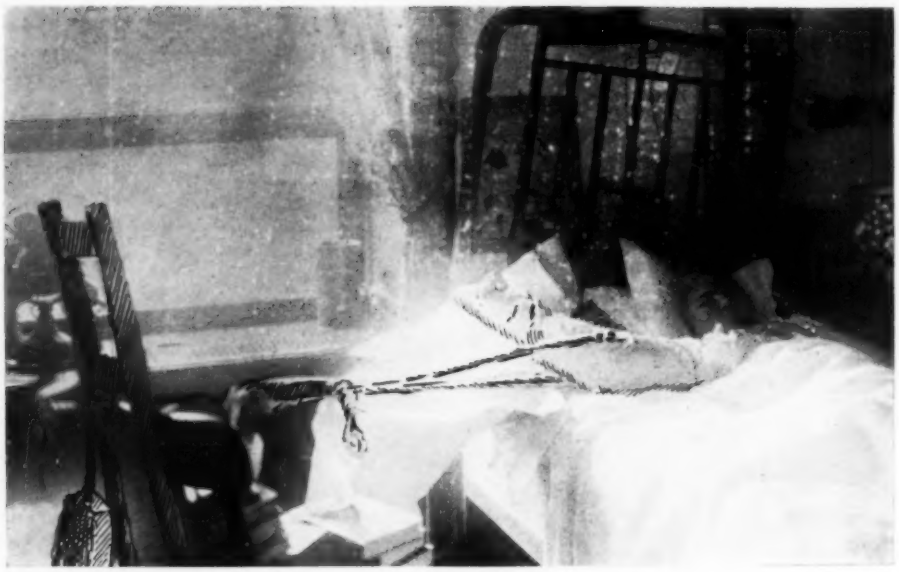

FIG. 16.—Shows right-angle splint in place with extension to arm. Head of bed raised on extension side. Splint *A*, Fig. 14, used in this case. X-ray of this case shown in Figs. 7 and 8. Final results shown in Fig. 18 on thirty-first day.

FIG. 17.—Showing active motion in Type III case on twentieth day. X-ray of this case shown in Figs. 7 and 8.

FIG. 18.—Type III case, showing active motion on thirty-first day. X-ray of this case shown in Figs. 7 and 8. Pain negligible in this case.

posterior splint, arm in abduction above a right angle and external rotation with an extension of eight pounds for twelve days. Fig. 8, which was taken twenty-five days after the original injury, contrasted with Fig. 7 will amply demonstrate what the extension accomplished. The splint A of Fig. 14 shows the splint used in this case and the one which we usually use. The other shown—B Fig. 14—is a type which we have used in special cases, but the one shown in A is the one which we prefer. This permits of passive motion at the shoulder while in place, and after the first six days the shoulder was gently moved for a few inches each day with the apparatus in place.

Coaptation splints to the broken humerus were used in this case, and on account of an extremely tender skin traction was obtained from a sling at the elbow instead of plaster along the arm, which is the better method because it permits free motion at the elbow during the period of confinement in bed. The apparatus in place is shown in Fig. 16. Treatment on account of the oblique fracture of the shaft was necessarily slower. The arm was moved a few inches each day after the sixth day. On the twelfth day, the arm, still in the splint, was brought down to an angle of thirty degrees, with the arm traction still in place, the forearm raised from the bed somewhat so as not to lie flat, because as the arm comes down in abduction the external rotation must be made less and less. The whole bone moved in continuity on this day.

Twenty-four hours later the arm was brought to the side, the splint and traction discarded, the arm gently rotated into internal rotation, and from this time on the patient was up and about—the forearm supported by a sling, the arm held to the body by a swathe. The coaptation splints were left on for some days longer. Passive motion was begun on the fourteenth day and on the sixteenth day passive motion almost to the full arc of abduction was reached. Active motion was begun on the sixteenth day, gently at first. Active motion was slow in returning, but Fig. 17 shows the degree of active motion on the twentieth day, and Fig. 18 shows the result at end of thirty days.

I have had occasion before to bring forward the contention that in fractures involving joints we have for years been making the most egregious blunders in the treatment, and our results have been atrocious.

A splint is of value only as a temporary support until enough callus is formed to prevent deformity. After that a splint is an injury. It is of use only until such time as the soft callus has formed sufficiently to protect the ends of the broken bone from again becoming dislocated and this period is very much sooner than we have been accustomed to believe. Of course no strain must be put upon the bone at this early date, and in lower extremity fractures it is a long time before actual weight can be borne, but the necessity of splinting, save that necessary to prevent injury by the patients themselves, passes very quickly, and in intelligent people who will exercise a certain

degree of care, fractures which do not involve weight-bearing will recover much more quickly if this rule is applied.

Actual bony trabeculæ are demonstrable across the broken surface as early as the twenty-first day, and enough stability is present long before this to permit of motion necessary to prevent the long tedious months of recovery which ensue when a joint that has been traumatized is locked up for weeks.

A Colles's fracture, even if properly reduced, if left in a splint after the tenth day is a case maltreated. Motion instituted from the first and removal of splints early will give surprising results. A Colles's is no longer a question of months: it is usually a matter of days. The same applies to a Pott's, save that here we must be careful of the weight-bearing and the weight of the foot itself—but early motion should be the rule.

The same reasoning and execution applied to fractures of the upper end of the humerus will give results which are no less satisfactory to the surgeon than to the patient and will save many an arm from partial disability.

CONCLUSIONS

1. Fractures of the upper end of the humerus, *i.e.*, above the insertion of the pectoralis major muscle, will in nearly all cases conform to three types and their subdivisions. All should be treated in abduction and external rotation with traction varying from a few days in mild cases to twelve days in complicated ones.

2. Passive motion must be begun early and active motion must follow very quickly if we are to prevent the tendency to restriction of motion. It must be used always with care and with due regard to the anatomy and pathology. In the mild cases it is safe to begin very early since there is little tendency toward displacement.

3. A right-angled wooden splint in the severe cases and a firm pillow splint in the mild cases always with traction is the ideal method of treatment.

4. External rotation in abduction as a treatment is almost an impossibility of accomplishment unless the patient remains in bed. In bed it is the simplest method and not an uncomfortable position for the patient.

THE USE AND VALUE OF THE LANE PLATE

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In view of the great interest evinced in the treatment of fractures during recent years, and, particularly, from the stimulation imparted to this study from the experiences of the war, I venture to present my personal view on one phase of the question of open operation for fracture of the long bones. I refer, specifically, to the use and value of the Lane plate as a method of fixation and immobilization. The individual surgeon is apt to deduce general conclusions from too few available facts. It is solely by a compilation of individual experiences and general debate of the topic that the truth gradually and finally crystallizes.

In the beginning of this discussion, I may frankly state that I am an advocate and partisan of the use of the Lane plate in certain types of fractures, particularly, fracture of the shaft of the femur, of the tibia and of the humerus. This conviction is based upon a series of sixty-two open operations for fractures. In the tabulation of this series, I have excluded all cases of fracture of the patella, because the surgical treatment of this type seems well established and generally accepted. Also, all cases of compound fractures are excluded. These sixty-two operations, then, are, in the main, open operations for simple fractures of the humerus, femur, tibia, radius and ulna. The methods employed for fixation were the Lane plate, silver wire, kangaroo tendon, nails, bone-graft and fascia lata. The Lane plate was employed thirteen times.

It must be recalled that in strong, robust and muscular individuals, with either a fracture of the femur, the humerus, or the tibia, presenting great displacement and over-riding and necessitating an open operation, a method of fixation must be employed which guarantees the successful reduction, in order that the advantage derived is not lost; and, that the patient is not exposed to a grave operation, solely, to have the immediate result and benefit vanish when the skin is sutured. In a word, if the method of fixation employed does not effectively maintain and rigidly secure the reduction, the patient is needlessly exposed to the danger and jeopardy of an open operation. It is almost unnecessary to call attention to the danger of open operation in which the aseptic technic is faulty. The risk to life and limb is too great to warrant undue experimentation.

From an ideal viewpoint a fixation apparatus capable of absorption should be the best. The introduction of foreign material, particularly, metal, into an open wound, does not appeal to the surgical mind. Ingenious contrivances and methods have been devised for the purpose of avoiding the

metal. This effort has been mainly in the direction of the invention of absorbent plates, screws and pegs of ivory, magnesium, decalcified bone, etc. Despite this, no commendable method exists which splints a bone so firmly as the use of steel plates and screws. Kangaroo tendon has been widely used for this purpose. While this material is excellent for a fracture of the patella, or to suture the radius, or the ulna, it is not sufficiently strong to maintain the reduction of the femur, the tibia, or the humerus. Even in a child, these bones are too large and heavy, and the muscles of the arm, the leg and the thigh too powerful for suture material so fragile to withstand. The same consideration underlies the use of chromic catgut. On one occasion, I used a long, narrow strip of the fascia lata, passed through two drill openings in the shaft of the femur. This patient, unfortunately, developed diphtheria several weeks later and was transferred to the Willard Parker Hospital. Owing to faulty records and failure to find the patient, the ultimate result cannot be stated. As a matter of interest, I may mention in passing, that this operation with fascia lata was done prior to the time—at least a year—when John B. Roberts called attention to this method of fixation.

My personal experience leads me to believe that certain types of fracture can be reduced and immobilized only by using the Lane plate. It is widely known that the use of the Lane plate is generally decried as being dangerous and uncertain. Indeed, many surgeons speak and write of it in scathing terms, and from a superficial study of the subject one might infer that the procedure is universally condemned as being unsurgical and dangerous. That it is not perfect, one must admit. The substitutes recommended may not always be effective and innocent. Incidentally, numerous therapeutic measures of acknowledged benefit and value, are not always one hundred per cent. efficient.

The objection, prominently advanced, is that the Lane plate delays callus formation and bone union. The validity of this objection is, admittedly, based on clinical experiences. But all methods of fixation, particularly, those using metallic objects, are open to this criticism. Indeed, it must be recalled, in fact, reiterated constantly, that no means of open operation for fracture hastens bone union, a cardinal point, generally overlooked in the discussion of this matter. The sole object of an open operation is to secure anatomic reduction of a bone. There is no method of fixation which hastens bone union or callus formation. Clinical observation and practical experience, in open operation for fracture, demonstrate that no method of operative fixation, or immobilization, using any form of internal splinting apparatus whatever, hastens the union of bone. An open operation is employed solely to reduce the bone to the normal outline and contour. Regarding the length of time necessary for the production of strong union, it is even possible that an open operation prolongs the period of union. Indeed, this is not an uncommon occurrence. But the delay of one or two weeks cannot be sufficient to militate against the selection of the operation. In

fact, as a patient may not be able to walk and use the limb with freedom and comfort for many months, despite any treatment employed, a matter of a few weeks is relatively unimportant.

An undue delay in union is emphasized by a bending or yielding at the site of fracture, at the end of the fifth or sixth week, a time when at least moderately strong fibrous or bony union should exist. The delay in union is generally ascribed to the presence of the foreign body maintained for the purpose of immobilization, a statement which is unquestionably true. In short, the Lane plate, while overcoming and preventing deformity, occasionally causes delayed union. If this takes place, no time should be lost in removing the plate. Under these circumstances, one generally finds that the Lane plate and the screws have been carried outward towards the skin incision by the expansion of the enveloping callus. This fact, combined with the natural atrophy of the muscles from the immobilization in plaster, places the plate and screws close to the incision. It is not difficult, therefore, quickly to remove the plate; local anæsthesia is generally sufficient.

It is important, in this connection, to emphasize the fact that the delay in union, seen in the use of the Lane plate, with the bending and buckling of the bone and the excessive callus formation, takes place just as often, possibly, following the use of silver wire. And in these instances of delayed union, following the use of silver wire, the silver wire, also, must be removed if firm union is desired; but, the removal of the silver wire is, as a rule, accomplished under great difficulties, because it tends to remain deeply buried in the centre of the callus.

Silver wire is the most widely used of all the means of metallic fixation. It possesses sufficient tensile strength and has an inherent antiseptic quality, due to the metallic silver. Several modifications have been advised, such as picture wire, bronze wire, etc., but in general, the fundamental principles are the same. The opponent of the Lane plate is ultimately forced into the position of becoming an advocate of silver wire. From my own experience, however, I have never yet seen a case in which silver wire has been used but some degree of angulation occurred. In a word, though silver wire prevents, as a rule, longitudinal displacement, it does not assure sufficient stability and rigidity to overcome the lateral deformity. As a result of this uncertain fixation, angulation and bending are prone to take place. One will recall that this is an objection to the Steinmann nail method.

There exists, perhaps, a technical reason for the angulation. While the introduction of silver wire through two drill openings is an extremely simple procedure, the twisting or tightening of the wire is not so easy. This step must be done with extreme caution, lest the wire break if tightened too suddenly, or to a point too extreme. It is possible, in some instances, that the silver wire has not received sufficient twisting, leaving, as a result, more or less slack within the suture. Even in the hands of experienced men, the twisting of the wire being carried to an extreme point, angulation will take place. If this angulation occur in a lateral and external direction, a direc-

tion favored, for example, by the normal outward bowing of the shaft of the femur, it is possible that the fragments may ultimately come in contact with the skin. Indeed, if the angulation be extreme, the bony fragments may rupture and protrude between the margins of the incision. This unfortunate accident is in no way occasioned by the occurrence of infection. It is natural, however, that when the fragments reach or rupture the incision, that a subacute inflammatory process will supervene, the recognition of which is extremely difficult. The X-ray is of but slight value in showing whether the fragments have ruptured the incision. If the angulation appear unduly extreme in the picture, or the temperature persists above 100 at the end of ten days, the cast should be removed and the limb closely inspected. The treatment of this complication consists in the removal of the silver wire. Once having been exposed to the air its removal is imperative.

In children silver wire is, perhaps, the best means of fixation, because they are not good operative risks and their tissues do not withstand so intense a degree of irritation as the adult. Moreover, if angulation take place in a child, the compensatory change and growth of bone overcome and correct the deformity. In regard to the development of a sinus, no doubt exists that silver wire, in many instances, produces a sinus which can be cured only by the removal of the wire. Under these circumstances, one is compelled to perform a secondary operation. Unlike the Lane plate, the wire tends to remain buried at the bottom of the callus, which must be chiselled or removed. This secondary operation greatly impairs the integrity of the union derived from the primary operation.

The Parkhill clamp has been, admittedly, of great value in the stimulating and devising of means of internal fixation in fractures. Though the clamp has been generally discarded, numerous modifications, based on the original principles, are, at present, widely employed. Though effective in holding the fractured bone in proper alignment, they possess in general a marked and distinctive feature, in permitting direct and continuous communication between the fracture and the external air, a point of technic directly opposed to the cardinal principles of asepsis and normal wound healing.

I have never used a bone-graft for a fracture of the shaft of the femur, because it seems to me that the physiological principles of this operation have never been clearly enunciated. That the bone-graft is distinctly incorporated and forms an integral part of the femur, has not been clearly demonstrated. If it is used solely as a means of fixation, the patient is exposed to the second danger of an accessory operation. Moreover, the danger of fat embolism is greatly increased. As the use of the bone-graft seems to rest ultimately on its capacity to stimulate osteogenesis, the risk included in the operative technic outweighs whatever advantages, productive though they may be, that the operation presents.

An open operation should seldom be performed for fracture of the femur in a child. The condition existing in a child is by no means analogous

to that in an adult. Also, a plan of treatment based on a reading of, or interpretation of X-ray pictures, may lead to the selection of the wrong method. In short, there may exist in a child a degree of overlapping of the fragments, which, if present in an adult, would definitely decide the necessity of an open operation; but, being in a child, in whom the condition of bone growth and compensation are so strikingly different, conservative treatment, and not the radical, should be instituted. This capacity of adjustment is due, or rather, receives its source, from the active, growing epiphyses. The bone being a vigorous, growing organism, appears to possess the capacity to compensate for any fortuitous shortening. In a child, therefore, with a fracture of the femur and excessive overlapping and displacement of the fragments, the union and result may be excellent, despite the original shortening. It is essential to keep this point clearly in mind.

In addition, there should be no cosmetic deformity. If a fractured limb, on inspection, appears to possess the normal contour, shape and size, it is probable that the ultimate outcome will be satisfactory. This rule has certain exceptions; but, in general, it can be used as a practical working guide. In the adult, however, the interposition of the muscular tissue between the ends of the bone is an extremely common occurrence and one prone to lead either to difficulty in the proper reduction, or failure of union.

A Lane plate represents the quintessence of aseptic technic. Those who have had the pleasure of seeing Sir Arbuthnot Lane operate must appreciate the painstaking and perfect work accomplished by this brilliant surgeon. The cardinal point in his impeccable technic, is that no finger or hand touches the gauze, the instruments, the plates, or the screws—in fact, anything employed in the operation, from the time of leaving the sterilizer until entering the wound. In many hospitals, it is impossible to introduce the Lane technic, save under great difficulty, owing to the rapid alterations in the personnel of the house staff, the constant changes in the nursing organization and the absence of standardization of technic. Certain important points, however, may be utilized.

The surgeon cannot be too meticulous in his demands and exactions. Of course, he and his assistants, including the nurses, should wear masks and rubber gloves. It is important that conversation be reduced to a minimum. Indeed, strict silence is enjoined, for it accelerates the operation. Before proceeding with the operation, the nurse in charge should be consulted, to ascertain definitely that the proper plates, screws and instruments are available. A particular point to be observed is that a drill of correct size and length is at hand. Great confusion may arise during operation from failure of the surgeon to determine previously that the necessary drill is available. The limb should receive careful preliminary preparation. It should be scrupulously cleaned, washed and scrubbed with ether, alcohol and benzine and painted with iodine. When the draperies are removed upon the table, one painting of iodine is sufficient. The surgeon should so arrange the time of operation that no appointments or engagements urge him to undue haste.

If possible, the Lane technic should be religiously followed. Two knives are used. The skin being considered a septic surface, the scalpel used for it is immediately discarded when the deeper structures are reached. The sterile towels are then clamped to the margins of the wound, so as to prevent an exposure of the surface of the adjacent skin. Allis clamps are extremely serviceable for this purpose.

A long incision is desirable. The manipulation of the bones is facilitated and vigorous retraction avoided, thereby, preventing undue traumatism to the soft parts. Moreover, if a long incision is made, it is not necessary to change the position of the draperies and the towels, in case the incision needs to be prolonged. The fascia lata is incised with the scalpel, making a clean incision. The muscular masses are best divided with a blunt instrument, preventing thereby, unnecessary division of the large arterial branches, and lessening, to a certain extent, the hemorrhage. As the wound, particularly in the thigh, is extremely deep, broad abdominal retractors serve best to expose the site of fracture and to identify the fragments. The periosteum may be disregarded during the manipulations necessary to free the fragments. This point, brought into prominence by Lane, receives confirmation and support from actual practice. An essential error in the technic is the violence and vigor employed in the manipulation of the bones. This entails undue force, favors tissue destruction and, incidentally, infection. The reduction should be made with a minimum of effort. In order to accomplish this the surgeon must endeavor to detect the restraining causes. These mainly consist in interposed fascia, periosteum, blood-clot and muscle. These structures should be pushed aside, if possible, to avoid the direct incision of the soft parts. To effect reduction the muscles should be freed from the shaft over a certain area close to the fractured ends. The extent of freed muscle-mass must be as short as possible.

The fragments, as a rule, are separated by organized blood-clot, fibrous tissue, periosteum, or numerous muscular slips. This interposed tissue should never be excised or cut recklessly. The close proximity of the shaft of the bone to the large arteries and nerves, does not permit an injudicious use of the scalpel or scissors. Each bone fragment should be isolated. In operating on the femur, I have noted that after the muscles have been separated, it is occasionally difficult to see the fragments. As a rule, one fragment comes into view. This fragment should be carefully exposed and cleaned, so that it can be mobilized. When this has been accomplished, the second fragment may be exposed. The ends are cleaned by mild scraping with a curette and all adventitious and fibrous bands removed or pushed aside. One should be extremely careful not to curette the open medulla too vigorously, for fear of causing fat embolism, an incident not uncommon in operations upon the shaft of the femur.

During the operation one assistant should hold the foot, in order to exercise traction, extension or flexion, as the surgeon directs. It is imperative that each fragment should be well mobilized before reduction be made.

Heavy bone forceps of the Lane type greatly facilitate the moving and lifting of the bones. Following reduction, the fragments are held in alignment with Lowman clamps, while the plate is adjusted and the screws introduced. The Lane plate is placed over the anterolateral surface of the shaft of the femur. A revolver bone drill makes a small depression for the entrance of the screws. Four screws are generally sufficient to hold a femur, though the plate is made for six, or even eight screws. It is best to use as small a plate as possible. Following the introduction of the plate and screws, the muscles are allowed to come together. The fascia is sutured with continuous catgut and the interrupted catgut for the skin.

A subtrochanteric fracture of the shaft of the femur furnishes an ideal indication for a Lane plate. There is no method of treatment which has the power and capacity to maintain immobilization in this type of fracture so efficaciously as the Lane plate. It is well known that a subtrachanteric fracture of the shaft of the femur is extremely difficult to reduce, the pull of the large thigh muscles being hard to overcome. Also the natural displacement, due to muscular contraction and retraction, offers peculiar difficulty to the proper reduction. I have, therefore, come to the conclusion that this type of fracture is one especially suitable for Lane plating. There are certain precautions, however, that one should observe in the routine use of the plate. The patient should be under forty years of age, strong, robust and in complete health.

A comminuted fracture of the shaft of the femur is not, as a rule, suitable for open operation. One generally finds that the fragments are so extremely splintered and short, that when grasped with a bone forceps, they easily break. This, naturally, prevents or even offers great difficulty in the proper reduction of the bone at the time of operation. The removal of these fragments, however, is a procedure fraught with great danger. I have seen instances where their removal caused non-union. Many of these fragments being triangular in shape and tapering to a thin edge, great care is needed in applying the holding bone forceps, for they may divide or break the fragments. Moreover, one finds great difficulty in introducing screws, nails, or wires.

Open operation for fracture of the shaft of the humerus is not as often indicated as in the femur, because a slight angulation or overlapping may exist, without disturbing to any appreciable degree the functional use of the arm. If, however, the swelling and deformity are extreme and one has reason to believe that marked over-riding exists, an open operation is indicated. A plate effectively holds the fragments in position. Two or three screws are at most needed. Care must be exercised to place the incision at a point where there is no danger of wounding the musculospiral nerve.

The Lane plate has a distinct field of usefulness in certain fractures of the shaft of the tibia, that defy reduction by traction or manipulation. It is not unusual, in fractures of both bones of the leg, to find that despite vigorous traction and manipulation on a Hawley fracture table, proper reduction

does not take place. Not only is the cosmetic appearance bad, but the X-ray verifies the displacement. In some instances, the reduction is prevented by the fragments, either the upper or the lower, passing between the opposite two. This type of fracture offers the Lane plate an excellent opportunity of success. Occasionally, however, in these cases, the Lane plate must be removed. One generally finds that during the period of healing the incision softens and separates, exposing the Lane plate at the bottom of the wound. The wound is permitted to granulate. There is generally no elevation of temperature or undue disturbance to the patient. Occasionally, but rarely, a slight sub-infection persists, despite the removal of the plate. This seems to arise from proliferation of the periosteum. The test of the applicability of the plate is that it restores the bone to its normal contour.

The patient should always be operated upon on a Hawley fracture table. It is essential that before the operation begins the surgeon adjust the patient to the table and have the companion limb bandaged to the foot-piece, so that the operation can be conducted expeditiously. In fact, it is better to cover the pelvis with cotton or flannel bandages before the operation so that no time is lost, or the position of the patient changed, in order to remove the dressing.

In the case of fracture of the femur, the patient at the end of the fifth or sixth week, is brought to the operating room and the plaster cast carefully removed, the catgut sutures are brushed away and the wound is cleaned and dressed. It is then preferable to apply a long, moulded, plaster splint, avoiding, incidentally, the compressive effect of a plaster cast. In this way, any tendency to pressure or bed-sores is obviated. The patient is kept in bed as long as possible, because the longer weight-bearing is postponed the better the final result.

Following an operation for the introduction of a Lane plate, the post-operative course should be carefully scrutinized. The temperature curve is of great importance. At times it is difficult to differentiate between a true infection and the development and manifestation of an ordinary wound-healing, associated with a large blood-clot. The detection of the presence of infection in the wound should be early, in order that prompt treatment may be instituted. One must recall, in this connection, however, that the post-operative complications incidental to any operation, may take place in this instance, necessitating careful and keen diagnostic discrimination. A daily supervision of the patient's condition, the pulse rate, the state of the tongue, whether pain is complained of, are particularly necessary. A prolonged elevation of temperature is extremely significant. The temperature following an open operation, in the case of an aseptic healing of the wound, reaches a low point about five days following operation. If the temperature persists after the sixth day, gradually attaining a maximum range of 103°, the presence of infection in the wound is extremely probable.

Owing to the migratory habits of the patients, it has been impossible to follow up the cases in detail, in order to determine the ultimate end-results.

Nevertheless, many of these patients have been observed for many months, while of some I have records extending several years, but owing to the somewhat incomplete end-studies, no attempt is made to furnish a complete statistical analysis. In this series of open operations, there are but two unfortunate results. In one a secondary operation was performed, while in the second, death took place from acute dilatation of the stomach. In the first, a young man with a badly displaced fracture of the femur, a Lane plate maintained perfect reduction of the fracture. At the time of discharge from the hospital the limb was in excellent condition. At a later date, however, he returned to the out-patient department, presenting excessive callus at the site of fracture and a marked bending of the bone. Naturally, he had employed too early weight-bearing on the limb. An oblique osteotomy of the shaft of the femur was employed for the correction of the deformity. A resulting atrophy and paralysis of the muscles of the leg, however, led to an exploratory operation in which the sciatic nerve was exposed and freed from excessive callus. A neuroma was encountered and excised and an end-to-end union made between the trunk of the sciatic nerve and the internal and the external popliteal nerves. The patient was later studied in detail, from the neurological viewpoint, by Dr. Joseph Byrne, who discovered distinct signs of regeneration, as evidenced by the return of protopathic sensibility. A trophic ulcer of the foot, however, became so progressive, that a modified Chopart amputation was done with excellent results.

In the second patient, with an extremely comminuted fracture of the upper one-third of the shaft of the femur, extending into the great trochanter, a final reduction was obtained by introducing a Lane plate. The wound became mildly infected, though no severe infection existed in the bone. The patient finally died from acute dilatation of the stomach, a diagnosis confirmed by autopsy. Upon reflection, it is evident that an open operation should not have been attempted. The extensive comminution and splintering absolutely precluded any attempt to restore the normal contour. The experience supports strongly the contention urged above, that a comminuted fracture of any degree should not be operated. The forcible efforts required to secure reduction caused, no doubt, a certain devitalizing of the tissues, which in turn favored the infection.

It is frankly admitted that the treatment of fractures in a general hospital is usually an exceedingly neglected subject. The enthusiasm and the ardent desire of the younger members of the staff for abdominal surgery, so spectacular and dramatic, and the general lack of equipment, such as beds, splints, fracture tables, etc., constitute the main reasons.

Great benefit may be derived from a definite system of treatment. The immediate first-aid treatment is, admittedly, beyond the control or the direction of the hospital. The duties of the ambulance surgeon, however, and the method of treatment employed by him, can be, to a certain degree, directed and systematized. For fractures of the extremities, plain lateral, wooden splints, neatly padded, are the best means of temporary immobiliza-

tion. The patient is brought to the hospital, as soon as possible, where he is referred to the house surgeon for the secondary or interim treatment. The wooden splints should then be removed and moulded plaster splints applied. In any case, the crucial point is that a temporary method of absolute fixation and immobilization is needed and that the usual means employed, the wooden splint, is at the best but a makeshift. It should be used but for a few hours, at the most, for if allowed to remain for a longer period, there impends the danger of pressure sores at the site of fracture, from the unyielding nature and hardness of the wood. Furthermore, wooden lateral splints tend to slide and slip, rapidly assuming a position the reverse of that in which they were originally applied, while the moulded plaster splint is quickly made, and affords the patient great comfort.

The preliminary method of immobilization is an important factor before the definitive treatment is selected. Undue displacement and movement are prevented and the patient transported with ease from his bed to the X-ray department. If marked swelling and bleb formation occur, wet dressings may be applied over the moulded plaster splints. The patient is then X-rayed and the plates studied by the visiting röntgenologist. The actual physical examination is generally postponed until the patient is anæsthetized, which is always done for reduction, whether simple or open. The physical and local symptoms are determined when the patient is under the anæsthetic and then carefully described and noted on the history chart at that time. Accurate measurements are also taken and recorded. Owing, however, to rapid changes of internes, absence of central control and to differences of opinion regarding treatment—in short, from lack of standardization, it is impossible to execute a specific plan, and will not be possible until a hospital service is conducted with the same efficiency as a factory—until the scientific parallels the industrial—that we shall have the ideal end-results.

The lessons we have learned, however, from the war and the discipline which has been instilled into our colleagues, will ultimately redound to the credit of the profession and influence, unquestionably, the future work and arrangement of the hospital staff. The effort toward the introduction of methods of efficiency in hospitals will be greatly accelerated when our colleagues return from their now perilous duties to the quieter work of peace. They will, no doubt, carry with them the advantages derived from centralization and authority of organization and the old-fashioned, or former staff of a hospital, with the various lines of cleavage of opinion, will be subordinated to the newer spirit of discipline acquired on the battlefields and transferred with all its merits to our civil institutions.

TRANSACTIONS
OF THE
PHILADELPHIA ACADEMY OF SURGERY

Stated Meeting, held December 12, 1918

The Second Vice-President, Dr. Harry C. Deaver, in the Chair

CHARCOT KNEES COMPLICATED BY FRACTURED LEG

Dr. John B. Roberts presented a man with Charcot knee-joints who had been under treatment for lues by Dr. B. A. Thomas at the Polyclinic Hospital prior to and subsequent to coming under Doctor Roberts's care for syphilitic fracture of the tibia and fibula of the right leg just above the ankle. This occurred about two years ago while the man was walking in the street. No undue force had been applied to the bones which simply gave way under him as he walked. There seemed to be nothing special in the X-ray appearances to suggest a bone dyscrasia. Doctor Roberts treated the fracture in a swung fracture box in the usual manner. Union took place and the man was discharged with what appeared to be a well-united fracture of the tibia and fibula. It was the opinion of Doctor Roberts at that time that the fracture was not due to syphilitic bone softening and the man was expected to have no further difficulty if he postponed weight bearing for the usual period after fractures at the ankle. A number of months afterward he came under Doctor Roberts's observation again and said that he had been walking without any special support to the fractured bones. The leg showed a large mass of bone and callus at the ankle with lateral and backward displacement at the seat of fracture. The appearances still exist but he has been wearing now a brace to prevent further deformity and disability. The Charcot knees are characteristic and the man has been under constant treatment for about four years, taking large amounts of potassium iodide and mercury and many injections of salvarsan and arsenobenzol. The long-continued treatment with the support given by the orthopædic surgeons to his knee-joints and to his fractured leg has brought this man to a condition which enables him to make a living, though when first seen by Doctor Thomas he could scarcely move the limbs which were supposed to be the seat of paralysis of doubtful origin. The man's indomitable courage and the wisdom of Doctor Thomas, his first attendant, have reconstructed his legs to an extraordinary extent.

ERRONEOUS INTERPRETATION OF X-RAY PLATES

Dr. John B. Roberts showed a boy who had sustained a fracture of the lower end of the humerus which under ether was determined to be a fracture

or diastasis of the external condyle of the humerus without displacement. The X-ray seemed to show considerable displacement of the fragment at variance with what the clinical examination suggested. He also presented the X-ray plates of an old man who had had a dislocation of the right shoulder-joint of the subcoracoid variety. Dr. Morris Booth Miller and Doctor Roberts reduced the luxation under ether and felt sure from the anatomical appearances and the surgical examination that the head of the humerus had been properly replaced. X-ray examination by a röntgenologist of experience was made. The report that came to the surgeon was that the bone was not completely replaced. The subsequent history of the case showed that reduction had been complete and the interpretation of the X-ray plate was erroneous. These cases are indications that the surgeon and the röntgenologist should work together in order to get the true meaning of X-ray results as shown in photographic plates. This statement, of course, corresponds exactly with what we all know is also necessary in pathological and surgical consultations; namely, that neither the surgeon nor the microscopist, nor the röntgenologist can depend entirely upon his own findings. Each special method of examination needs at times to be checked up and correlated with the clinical or pathological or radiological examination, as the case may be.

POST-OPERATIVE INFECTIONS OF THE PAROTID GLAND

Dr. John B. Deaver read a paper with the above title for which see page 128.

Dr. Moses Behrend said that two months ago he operated on a case, removing the gall-bladder and the appendix. Two days later the parotid gland on one side became inflamed. The following day the gland on the opposite side was affected. The pain was intense and both glands had to be incised. The man had double facial paralysis which, however, entirely disappeared. He believed the paralysis was due not to the incisions but to the enormous pressure upon the facial nerves. The man had complete control of lips, corners of mouth and cheeks before he left the hospital. The case seemed of special interest because both sides became involved. In one other case following a minor operation the man developed an infection and later a severe parotitis. Numerous incisions were necessary to get rid of all the pockets of pus, the patient making a complete recovery without facial paralysis.

Dr. J. Torrance Rugh remarked that the mouth presents the most profuse bacterial flora of almost any of the cavities of the whole body. If mucin acts to limit the development of bacteria, why then should there be such great number and variety of bacteria in the mouth?

Doctor Deaver, in closing, said that the case to which Doctor Behrend refers he saw. The source of the infection in that case was probably the tonsils. The patient had a cardiac lesion. There was an acute infection of the parotid gland with deep suppuration. An incision was made into the gland

by Doctor Behrend. Doctor Deaver regarded this case as an instance of hæmatogenous infection. He frequently had this type of infection in suppurative appendicitis and other infectious conditions. He had seen abscess of the pancreas result from infection elsewhere in the abdomen.

RENAL CALCULI

Dr. F. A. Mantz (by invitation) read a paper with the above title. He said: The predisposing causes of renal calculi are sedentary habits, high living, and poor hygienic surroundings. The formation of these calculi is dependent upon the condition of the excreted urine, rather than upon an inflammatory process of the renal mucosa. However, there are exceptional cases; as pyelitis has been followed by extensive and massive stone formation in the kidney.

In order that these concretions may form, there must be of necessity an excess of certain of the solid constituents of the urine, which are most frequently urates, phosphates and oxalates. An excess of any of these salts favors a coagulation necrosis of the renal cells, thus forming a good nucleus for the deposit of any of the excessive salts that are present.

The symptoms depend more upon the position of the calculus than upon its size or shape. A calculus in the parenchyma or in a calyx, not infected and non-motile, may give rise to no symptoms at all. This fact has been proved by the X-ray examinations of patients suffering with other conditions than renal calculi, the calculi present being discovered accidentally in this way. The principal symptom is pain, radiating in a line to the bladder, scrotum and meatus, together with a desire to micturate. The urinalysis reveals red and white blood cells, pus and hyaline casts. Anuria is a symptom of bilateral lesions, but may be present when the lesion is unilateral, and is then caused by reflex action upon the other kidney.

To establish a positive diagnosis and to determine the proper treatment, we must call to our aid the cystoscope and the X-ray. The cystoscope reveals alterations in the flow of the urine from the ureter of the affected side; and catheterization of the ureters and examination of the two urines separately with the use of the phthalein test will determine whether or not the other kidney functionates sufficiently to carry on the necessary renal elimination, in case a nephrectomy is deemed expedient. Likewise, a wax-tipped ureteral catheter, as employed by Dr. H. A. Kelly, may be passed, to corroborate the presence of a suspected calculus when the X-rays fail to show a shadow. The X-ray examinations must be entrusted to the most experienced röntgenologist available—one who is able to interpret properly the skiagram and to differentiate the different shadows; since the uric acid and phosphatic calculi hardly cast any shadow, while the oxalate *stones* cast a strong shadow. The röntgenologist is often able definitely to locate the calculus, and thus facilitate its removal.

Having definitely diagnosed the presence of a renal calculus, its size and location, and whether the lesion is unilateral or bilateral, we must further

analyze the patient's physical condition, so as to determine the safest and best method of effecting *the desired cure*. The principles of renal-calculi surgery are to-day so scientifically sane and sound that, by adhering to them, the mortality due to these operations may be kept very low. By making such a thorough analysis of the case, we can nearly always determine before operation whether a nephrolithotomy is required, or a pyelotomy or a nephrectomy.

We should do a nephrolithotomy only when it is utterly impossible to remove the calculus by doing a pyelotomy. As a rule, all renal calculi are friable and easily crushed. Hence, most of the larger stones that fill the renal pelvis and calices may be crushed with an ordinary Kocher hæmostat or other forceps, and removed piece-meal, by way of the pyelotomy. Afterwards, the cavity should be thoroughly flushed with a normal saline solution or a mild antiseptic, to wash out the small remaining fragments or sand.

The risk of having a severe secondary hemorrhage following a nephrolithotomy far overbalances the probability of a permanent urinary fistula as the result of a pyelotomy. These secondary hemorrhages, which usually occur from the eighth to the tenth day after a nephrolithotomy, are always severe, and constitute a great source of annoyance and embarrassment to the surgeon who is fearful of being obliged to do a nephrectomy, which would have very serious consequences in a case in which the other kidney did not functionate sufficiently to carry on the required elimination.

A nephrectomy should be attempted only when there are many stones within the kidney, or when there is one large stone with an associated infection and destruction of the parenchyma.

The nonoperative cases include those in which a renal calculus is found in an extensive X-ray examination for some other condition, and in which the stone gives rise to no symptoms; especially so, when the patient is a poor surgical risk. On the other hand, all cases with an associated complication, such as extensive pyelitis, hydronephrosis or anuria, should be operated upon as soon as possible, even though the risk may be great; also cases in which the calculus has passed from the renal pelvis into the ureter and has there remained lodged, if, within a reasonable time, it does not find its way into the bladder. A calculus within the renal pelvis or in the parenchyma, giving rise to the symptoms of renal calculi, in a patient who is a good surgical risk, should be removed immediately, to avoid possible complications and sequelæ.

There is no drug that will dissolve a renal calculus within the human body. However, it is essential to treat the patient systematically after the operation, in order to prevent further stone formation. Diluents, such as distilled water in large quantities, to dilute the solid constituents of the urine, should be given; and a limited diet should be employed. No red meats should be allowed; but cereals and vegetables of all kinds, except rhubarb, tomatoes, asparagus and strawberries. Sugars, malt liquors and wines are interdicted, especially in the cases of those patients who are of a gouty diathesis. The free use of saline purgatives is imperative.

FIG. 1.

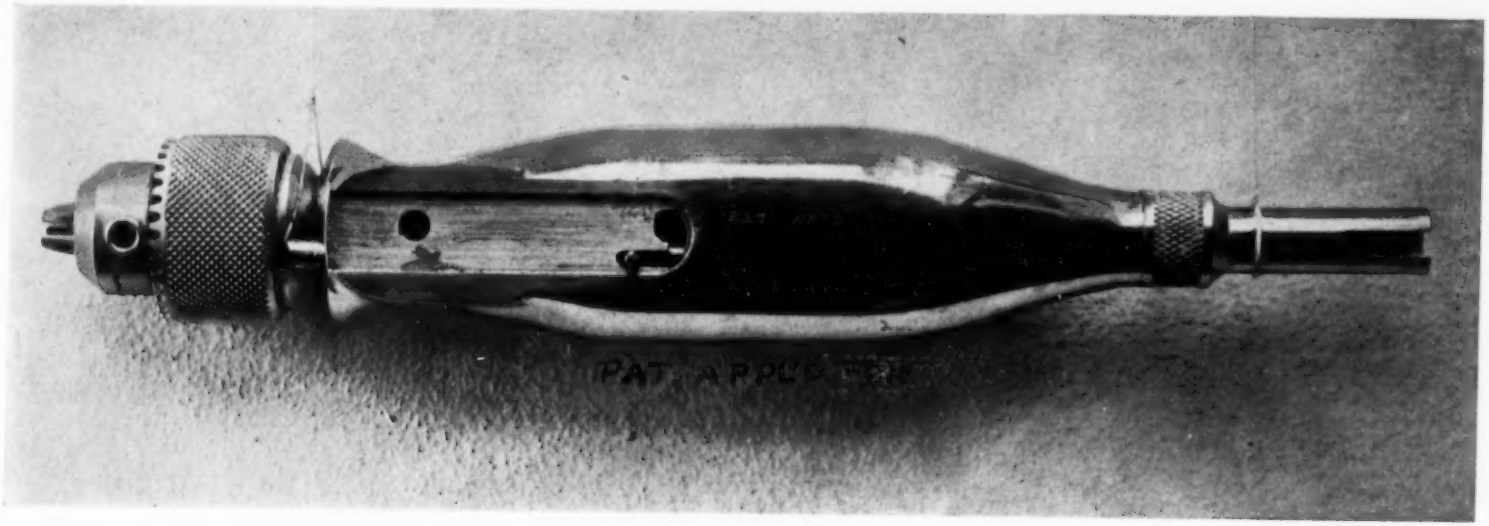

FIG. 2.—The tool-holder.

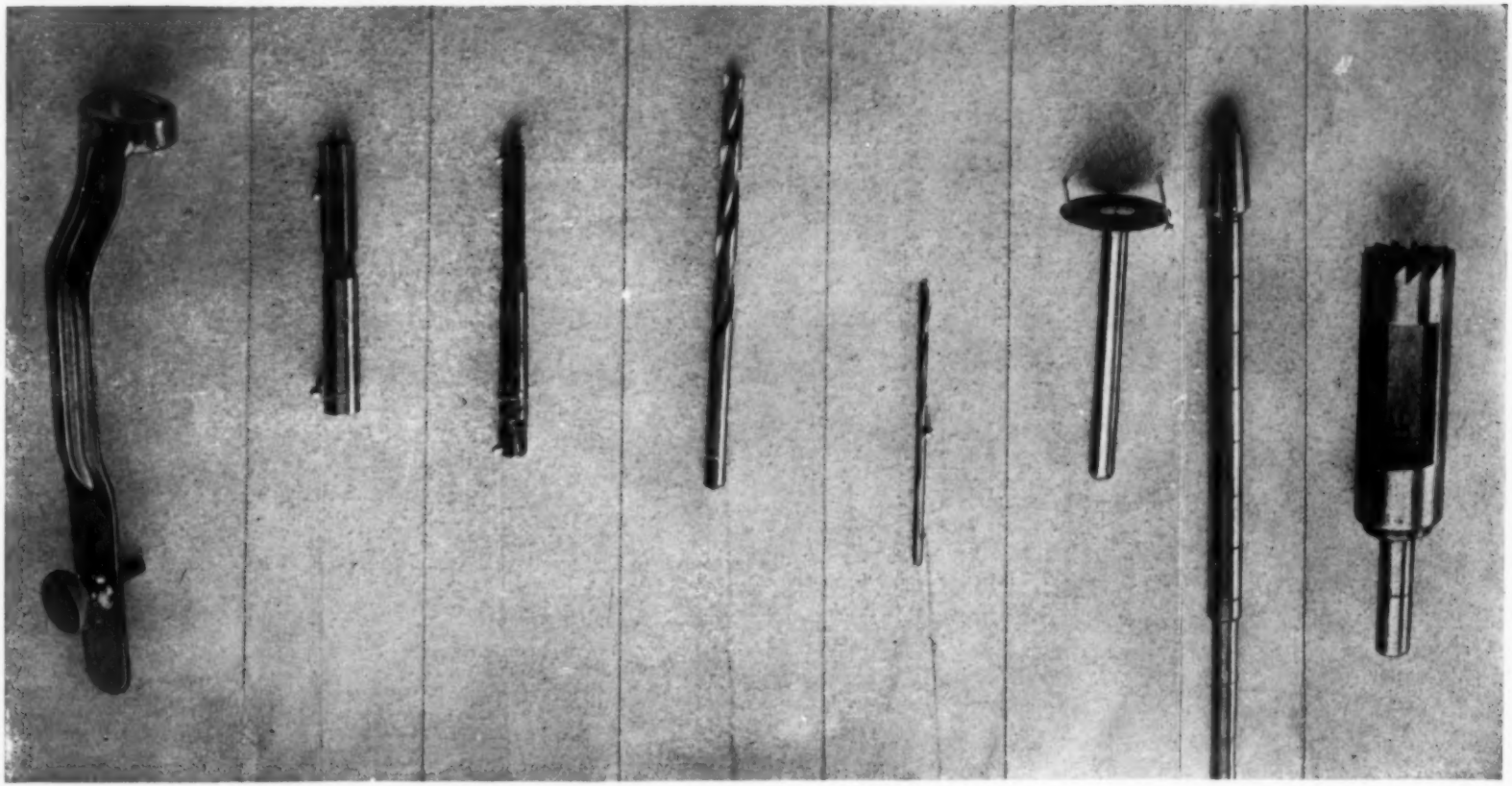

FIG. 3.—Drills, burrs and trephine.

Post-operative anuria is reflexly caused by the rough handling of the kidney and the effect of the anæsthetic. Personally, however, I believe that this complication can, in a great measure, be prevented by giving the patient large amounts of distilled water with potassium citrate, a few days before the operation, in order to render the urine bland and stimulate its flow. Morphine sulphate, one-quarter to three-eights of a grain, with 1/150 of a grain of atropine sulphate, should be administered half an hour prior to operating, for its anoci-association effect; but no morphine or atropine should be given after the operation.

Following the surgical procedure, normal saline solution as per the Murphy drip, should be administered, and plenty of water by mouth, as soon as the patient is able to retain it. Occasionally, also a mild diuretic may be given. These remedies constitute about all the medication necessary after the operation.

Dr. John B. Deaver said with reference to the passage of stones that failed to show a shadow, to which Doctor Mantz had called attention: They are difficult cases, and he recalled a number. One case seen recently was that of a man from the South. He had the symptoms of bloody urine, renal colic, pain, etc. He was referred to the röntgenologist. The report came back that the man did not have a stone, but that there was a tubercular area in the kidney. Another good röntgenologist said that the X-ray examination of the kidney was negative. The man was then cystoscoped and the operator said he did not know what the man had but that the blood all came from one kidney. Doctor Deaver made an exploratory exposure of the kidney and the result was the finding of a stone one-third the size of the fist in the kidney. He then called up the first röntgenologist who said he would like to have the stone. He put it in water and could not get a shadow. The case was one of those impossible of diagnosis because of the quality of the stone. No doubt there occur many such cases which slip through our hands.

NEW BONE SAW EQUIPMENT

Dr. H. C. Masland (by invitation) demonstrated the new bone saw equipment devised by him. It consists of two major instruments quickly adjustable to a flexible shaft of ample strength, driven by an electric motor.

One instrument is a circular saw mounted in a very convenient handle. The saw has a gauge immediately adjustable to cut any depth desired. This can be drawn back and an inside guard attached which protects the dura in cutting the skull or any other underlying soft tissue when the saw is used elsewhere. The nose of the instrument is about one inch wide, so that the saw can be used on deep-lying bones for either a vertical or a bevel cut.

The other instrument is a universal tool holder having a construction to facilitate the performance of various other operative procedures. Drills from the size of catgut up. Burrs of various types and sizes, a special trephine for opening the skull safely, hollow mills for bone pins, side cutting

mills to make level floored gutters for inlay work, a small circular saw, taps for threading holes and dies for bone pins.

This tool may be power driven or immediately detached and used as a hand instrument.

The doctor drives his instruments at low speed and thereby eliminates burning and does not need the water drip. The equipment meets rigid aseptic requirements.

Dr. J. Torrance Rugh said that he had always felt that the difficulty in this type of operating device was in the cable, and this problem Doctor Masland seems to have solved. The majority of these cable-operated machines keep jamming and bending, but Doctor Masland has a cable which is powerful enough to drive the instrument evenly. It has the advantage also of being of a size convenient to handle in the field of operation. Doctor Masland tells us that the cable may be boiled, but it must have oil, and the speaker would feel a little doubtful about boiling it. He suggested a device such as may be used on the Albee machine. For the supply cord there is a long tube or muslin casing running up to the handle of the motor. Some have a motor of the same type as Doctor Masland's and wrap the whole thing in a sterilized casing when using it and have no trouble about asepsis.

Another feature which commends this machine is that it is a low speed motor. He had never felt favorably inclined toward a high speed motor in bone work. It will burn the bone unless water is used, and many other inconveniences attend its employment which are eliminated by the low speed machine.

Dr. Moses Behrend said that with the Albee instrument one must hold a rather heavy motor; but with this the toolholder of Doctor Masland can be held with one hand. The Albee motor will often jam, as has been said. Doctor Masland's does not do this on account of his slow speed motor. The chuck is almost perfect; it will hold a hair. The smallest kind of a drill can be used which is a distinct advantage. Also the chuck is commendable because one can put in almost any sized instrument.

Doctor Masland, in closing, said that his first sleeve was of the usual dental composition type, covered with a sterilizable muslin sleeve. This did not appeal to him as thorough asepsis. His present cable and tubing are metal throughout, save for the asbestos packing in the crease of the spiral of the tubing to make it water-tight. The sleeve is brass, nickel-plated, and of the same construction as gas or speedometer tubing. A little heavy grease is used for lubrication. This will not run out through the accurately fitted ends. If it did it could be prevented by elevating the ends of the flexible shaft in the sterilizer.

THE SEGMENT TREPHINE

Dr. John B. Roberts remarked upon the evident efficiency of this saw of Doctor Masland. Those who have worked in bone surgery of the skull have realized the trouble with ordinary saws and trephines. Years ago he

FIG. 4.—Roberts's cranial trephine, made in 1882, to be driven with Bonwill dental engine.

FIG. 5.—Roberts's aseptic trephine, late model.

FIG. 6.—Roberts's aseptic segment trephine for making trefoil-shape flaps of bone in resecting the cranium.

undertook to use the Bonwill surgical engine for driving burrs for bone work on the extremities and head, but found it difficult to keep in order in surgical operating rooms. The little cranial trephine, which Doctor Masland has adopted to use with his outfit, Doctor Roberts had made for cranial use about thirty-five years ago, when he demonstrated that one could safely trephine the cranium by boring holes with a flat fissure burr. An entrance could thus be made into the cranium without damaging the dura. This little trephine (Fig. 4) with its conical shape and spiral cutting surface has a way of jamming itself when the saw edge of the crown cuts through the bone to the dural surface. Doctor Masland's experimental work with him, in the laboratory and on patients with his new saw, has revived the use of this instrument. The electric motor and cable which Doctor Masland uses in connection with his saw drives the trephine very satisfactorily. The instrument is easily sterilized and has a small hole through which it may be cleaned and the button of bone pushed out if it remains caught within the trephine. It needs no centre pin, or a drain with a centering point, though the latter could be fitted to it. Through small holes made by this instrument the Gigli saw may be used, if the Masland saw is not at hand, to make the osteoplastic flap to be turned down for access to the brain surface. Some years ago Doctor Roberts devised an aseptic trephine without the old-fashioned centre pin, which is familiar to many of the Fellows. He now showed a new model (Fig. 5) recently made for the army by Pilling. It is in some respects not as satisfactory as the original made by hand at the time when surgeons began to do operations for the removal of brain tumors, twenty or more year ago, but large numbers of the present form can be made by machinery and therefore at a much lower price. It does not need the stem which the instrument maker has put upon the drum which carries the centre pin. He also showed (Fig. 6) the aseptic segment trephine which does well in making clover-shaped flaps in resection of the skull for entrance to the cranial cavity when special saws like the Masland saw are not at hand. It and the various methods used to do osteoplastic sections are valuable now that surgeons always try to have bony closure of the gap made in the cranial wall. The methods which depend upon cutting away with gnawing forceps the bone and leaving great openings to be closed only by fibrous tissue have become antiquated and are to some extent looked upon as survivals of pre-Listerian surgery.

TRANSACTIONS

OF THE

NEW YORK SURGICAL SOCIETY

Stated meeting, held December 11, 1918

The President, Dr. Charles H. Peck, in the Chair

RESECTION OF SUPERIOR MAXILLA

Dr. Winfield S. Schley presented four patients who had been subjected to operation for cancer of the superior maxilla. The first was a man, forty-seven years of age. Six months before admission to hospital left naris became entirely occluded. He was told he had a nasal polyp, which was partially removed without benefit. Later removed again by his physician and submitted to microscopic examination. Pronounced sarcoma. When seen left nostril tightly blocked and cheek bulged perceptibly. At operation the antrum was completely filled with tumor and the left naris up to the ethmoid. Tumor proved to be a giant-celled sarcoma. A very complete excision was done.

Patient presented to show condition after three years and the simple prosthetic apparatus with teeth that the dentist has made. His speech is practically normal, as is mastication.

The second patient was a man, fifty-three years of age. Four years before admission he had the first nasal polyp removed. For over three years the left naris has been more or less occluded. Three months ago he was operated for polyp of left naris. Rapid recurrence. Another removal with microscopic examination showed "simple polyp." When first seen the left nostril was almost completely blocked and cheek bulging had begun. A specimen taken at a deeper level showed squamous-celled epithelioma. At operation extensive disease of left side of naris and whole of antrum existed. An extensive resection was done. He was now presented to show extent of epithelial growth and repair after three months and to illustrate again the danger of mistaking deep-seated malignancy for simple nasal polyp.

The third patient was a woman, forty-seven years of age, who twelve years ago first noticed a small mass upon the gum of the upper jaw opposite the canine tooth and apparently attached to the bone. In the ten succeeding years eight or nine local operations were done. When first seen she presented marked tumefaction of the right cheek under scars of previous operations. At operation the tumor tissue was found filling the antrum, the anterior wall of which had been removed at a previous session. A complete local excision of tumor (giant-celled sarcoma) was done and the antrum and tumor area strongly radiumized. No sign of recurrence after a year and eight months.

This patient presented to show a low type of malignancy probably starting as a giant-celled epulis.

Lastly was presented a patient with a much neglected case of squamous-celled cancer of the left upper jaw that had crossed the midline of the hard palate. A two-stage operation was done. Glands of neck and whole of jaw of affected side and later hard palate of opposite side. Ultimate recovery doubtful. Case presented to show importance of neck dissection in carcinoma of upper jaw. *Her lymphatic involvement in the neck was upon the opposite side to the primary and major growth.*

Dr. Adrian V. S. Lambert presented a woman, sixty-five years old, who was admitted to the Presbyterian Hospital, on June 7, 1915, with the history that three months prior to admission she noticed a swelling along the inner side of the gum on the left side of upper jaw. At first this grew very slowly, if at all, but during the past month it had increased rapidly in size and had extended backward along the roof of the mouth. She had no pain or discomfort except that due to her inability to wear her plate, in consequence of which she believed she has lost ten pounds.

On admission her physical examination showed a fairly well-nourished woman apparently suffering no pain. She had a diastolic murmur over the third left intercostal space near the border of the sternum. On the left side of the roof of the mouth there was a tumor mass extending from the alveolar margin behind the anterior arch backward to the posterior border of hard palate. This mass also extended a trifle beyond the median line. It was irregular in contour, having a rounded prominence near the alveolar margin and a large crater-like ulcer near the median cavity. The antrum seemed to be free of any involvement. No cervical lymphatic glands could be palpated. The skin of the face did not appear to be involved anywhere. A section of the mass was taken a week prior to operation and was reported "epithelioma of roof of mouth." The buccal cavity was kept clean for a week prior to operation. This was done with mouth washes and irrigation.

On June 14, 1915, a partial removal of the maxilla was done. The external carotid was ligated as a preliminary step just prior to the removal of the main mass. The Weber incision was used. This gave an excellent exposure. The floor of the orbit was removed together with the infra-orbital margin, and the incision passed to the right of median line along the hard palate. The maxilla was removed except a portion of its nasal process. The soft palate was not removed. She made a good post-operative recovery and left the hospital on the eleventh day post-operative.

She was seen in the follow-up clinic on July 18th, one month after her operation. She reported everything as progressing well. She was seen again on August 22nd, and several subcutaneous nodules in the scar at the angle of the eye and nose were noted. A positive diagnosis of recurrence was not made at this time. She was seen again on October 26th when she had a well-marked recurrence on the nasal process of superior maxilla. This was a hard nodule, reddened with skin glazed over it about 2 cm. in

diameter. It is very hard and shows a slight ulceration on the summit and is firmly adherent to the deeper parts.

She was operated on a second time October 28, 1915. The growth and an area of skin 1 cm. wide from its margin were removed. The inner canthus of the eye was preserved. The nasal process of superior maxilla was not removed but was bared of periosteum. A flap was then taken from the centre of the forehead to fill in the defect and was swung about a pedicle having its blood supply from the frontal artery of right side of nose. This was sutured into the defect. The post-operative course was uneventful except for slight infection at lower edge of flap, and she left the hospital on the eleventh day post-operative.

She has been seen in the follow-up clinic every six months and had not been willing to have any plastic on the redundant flap. The sinus at inner angle was not noticed in June, 1918, and has appeared only lately.

HYDRONEPHROSIS CURED BY PLASTIC OPERATION

Dr. Hermann Fischer presented a man, thirty-two years of age, who for three years had been suffering from attacks of pain on the left side of his abdomen.

The pain starts in the lumbar region and radiates towards the abdomen. The attacks occur at irregular intervals and in the last three weeks he had five such attacks. The pain is almost unbearable and is accompanied by nausea and vomiting. In between the attacks he feels quite well.

On examination in the height of an attack there was found a tumor the size of a child's head, in the region of the left kidney. It moved downward with respiration, was globular and smooth in outline, and had a cystic feel. A few days later, the tumor was much smaller, although still easily to be felt. His pain, however, had left him and he felt much better.

On entering the hospital on August 30th, he had another attack of pain and on examination the tumor was again as large as at the first examination.

X-Ray.—Shows an enlargement of left kidney, but no stone.

Cystoscope showed normal bladder; right ureter opening normal, easily entered by catheter; left ureteral opening much smaller, cannot be entered by smallest catheter at hand. Urine from right side normal. Phenolphthalin, 54 per cent.

Diagnosis.—Left hydronephrosis.

Operation.—September. Bergmann incision. Large hydronephrosis was found with almost normal kidney. There were no anomalies of arteries. The ureter close to the pelvis was narrowed, but no outward signs of inflammation around ureter could be ascertained. The ureter was inserted very high into the pelvis.

As there was no indication for removal of the kidney, a plastic operation was decided upon.

The pelvis of the kidney was opened by a longitudinal incision near the insertion of the ureter. The spur that was formed by the insertion of the

ureter and the distended pelvis below the insertion of the ureter was also incised longitudinally and sewed together transversely. In this fashion the spur was obliterated and the uretero-pelvic junction placed at the lowest point of the pelvis. By excision of an elliptical piece, the pelvis was narrowed.

Suture of pelvic incision by fine catgut; small cigarette drain was led down behind the kidney, and the wound closed up to the drain.

A pelvic fistula developed after removal of tampon on the tenth day; this, however, closed after two weeks.

The wound is now healed and he is free from pain. It is very difficult to account for the condition presented by this man. Tuffier was the first one to call attention to strictures of the ureter which were produced by inflammatory conditions, mostly gonorrhœa. The reporter thought that the pouching out of the pelvis of the kidney was secondary and not primary; it is caused by the pressure of the retained fluid. The moving of the ureter upward is also secondary, brought about by the sagging of the lower pole of the large hydronephrotic sac. It is difficult to see how a cure can be effected by simply diminishing the size of the sac by sutures. If there is an infection present he doubted whether a plastic was desirable.

Dr. Charles H. Peck stated that many of these cases are due to high implantation of the ureter and valvular obstruction. He had tried the operation that Doctor Fischer describes once without success. A number of cases were treated by resection of a portion of the redundant or hooded pelvis. For a number of years it has been his practice to pass a ureteral catheter from the nephrotomy wound down the ureter to the bladder and leave it in place for a few days, to prevent kinking or obstruction of the ureter while the kidney was becoming fixed in its new position. By this method many kidneys with early hydronephroses may be saved.

WOUND TREATMENT WITH CHINOSOL AND SALT

Dr. William C. Lusk presented the following seven patients: 1. Wound of tendons of wrist. 2. Empyema cavity. 3. Colon bacillus cellulitis. 4. Staphylococcus cellulitis. 5. Staphylococcus abscess of face. 6. Pelvic sinus. 7. Old wound laying open entire ischiorectal fossa, in the treatment of each of whom chinosol and salt had been used. Notes on these cases will be included in an original article which is to be published shortly.

Dr. Robert T. Morris stated that his results had been practically like those of Doctor Lusk in the use of chinosol. Until he had taken up the Carrel-Dakin method for treatment of wounds chinosol solution used in the strength of bichloride solutions had been his main dependence as an antiseptic. He had not used it with the salt nor in the strength quoted by Doctor Lusk. Chinosol solution made an excellent hand preparation, particularly when one had to do a series of operations in succession. It made an excellent non-toxic immersion bath for infection of the extremities.

"THE OPERATIVE TREATMENT OF CANCER OF THE SUPERIOR MAXILLA"

Dr. Winfield S. Schley read a paper with the above title.

Dr. Robert T. Morris stated that it seemed to him that preliminary ligation of the carotid was of advantage in operations for the removal of the superior maxilla for two reasons. There was less blood in the field while the surgeon was at work, and furthermore, the principle of starving the neoplasm appeared to have some evidence in its favor. Change in the rate of blood determination to a locality appeared to have special influence upon morbid cell construction. Sometimes when he had removed lymph-glands from the neck which appeared not to be enlarged little nests of epithelium had been found in cases of carcinoma involving the superior maxilla. The speaker had used paraffin injection for permanent elevation of the orbital structures after the orbital plate had been removed.

Dr. Adrian V. S. Lambert said that in the few cases of upper jaw removal that he had done he had only tied the external carotid and obtained a very satisfactory hæmostasis. He was surprised to hear mentioned the ligation of the common carotid in the same class as that of the external. He had only ligated the common carotid once and that was not very successful. It is a very serious surgical procedure, while the ligation of the external carotid, as Doctor Schley has shown, is attended with hardly any fatalities.

Dr. Hermann Fischer said that before the days of general anæsthesia the mortality after resection of the superior maxillary bone was low; when general anæsthesia was introduced the mortality rate increased on account of the frequency of post-operative pneumonia. He usually operated having the patient in a half sitting position under morphine-ether narcosis. The patient must not be deeply narcotised, pharyngeal reflex not abolished, so that he is still able to swallow. Laryngeal insufflation is also a very satisfactory method of narcotising these patients. By these means post-operative pneumonia can be avoided. He always does the operation in two stages, first ligating the external carotid artery and removing all the lymph-glands *en bloc*, from the omohyoid gland upward. Two or three days later resection of superior maxillary bone. He always removes the glands on the side of the lesion, whether they can be felt enlarged or not. He thought this was a very important point.

Dr. Charles H. Peck stated that intratracheal anæsthesia was very useful in cases of this type. The first case in which he had ever used it was in resection of the superior maxilla and ethmoid for sarcoma. The method prevents aspiration of blood and mucus into the trachea. Intra-pharyngeal anæsthesia does not answer the same purposes because it does not guard against this danger.

Dr. W. S. Schley in closing remarked as to the use of intratracheal anæsthesia, that with the lower jaw it is more necessary than in operations upon the upper as it is more difficult to keep blood out of the pharynx. With

external carotid ligation in upper jaw operations the bleeding is small and little or none of it passes the nasal tubes with light gauze packing at the back of the pharynx. The packing does not interfere with the breathing and the field of operation is so wide open that one has very little difficulty in controlling any moderate hemorrhage that occurs.

In the early history of this operation there was a large mortality from sepsis, from hemorrhage and pneumonia. We have practically eliminated the first two and pneumonia is no more frequent than after any operation.

The speaker thinks intratracheal anæsthesia is perfectly feasible here, his preference, however, as said, has been the nasal tubes with the pharynx packed; and it works apparently very well.

The two-stage operation is good. He would rather not do carotid ligation more than two days before the jaw operation as the anastomotic connection is sometimes very quickly established. He would rather do it at the same time as it consumes but five or ten additional minutes. If the external carotid is ligated well above the bifurcation, at or above the superior thyroid, the mortality from embolus is practically *nil.*

So far in the cases he has done there has been no operative mortality, and all have had extensive operations, even in three stages if necessary. There are a great many more cures than recorded so far.

EDITORIAL COMMENT

GORDON HOLMES ON THE TREATMENT OF SECONDARY AND LATE COMPLICATIONS OF BRAIN WOUNDS*

At the Interallied Surgical Conference of November, 1917, Mr. Gordon Holmes presented a report based upon the examination of 2357 patients who had been admitted into the hospitals of the United Kingdom for gunshot wounds of the cranium, affecting the brain directly or indirectly. In a certain number of these the wounds were of recent date, the others had not yet recovered from the immediate effects of their wounds at the time when the last medical reports as to their condition had been made, but there remained about 1567 cases in which it was possible to study secondary complications. All these cases dated back to at least three months before, and many have been followed for two or three years after their wounds. The clinical reports upon these patients have been obtained from different sources. In most cases they were derived from examination of the hospital records collected by the Committee on Statistics and Medical Research of the military and civil hospitals of the United Kingdom. As to a considerable number of men more seriously injured, the information was obtained from the reports of the Minister of Pensions. Five hundred and twenty-six cases were observed by the author personally during the first periods of their wounds in the hospitals in France, and their later condition he had followed since. These are included in this list.

The research has been limited to those wounded in the years 1914 and 1915, so that a sufficient period had elapsed for the evolution of later complications to have taken place. As the first surgical treatment of wounds of the brain has certainly been improved during these last two years, it may be hoped that secondary complications will be less and less common, much less than has been the case in the patients who are the subject of this present report.

Abscess of the Brain.—After healing of the wound, 37 cases of secondary abscess have been observed. In 28 instances these abscesses supervened between the third and sixth month after the wound; 4 between the sixth and seventh month; 3 between the eighth and ninth month; 1 during the tenth month; and 1 only after that period, namely, in the eighteenth month. It appears then that abscesses are more rare six months after the wound.

They have been observed in all types of penetrating wounds of the brain, but late complications were not met with in cases in which the dura mater had not been lacerated by the projectile or opened by the surgeon.

In most cases abscesses have developed directly at the level of the cranial

* *Comptes-Rendus de la Conférence chirurgicale interalliée pour l'étude des plaies de guerre*, 3e session, 5–8 Novembre, 1917.

wall and in many cases in the brain substance which had herniated. In cases of many wounded, however, they had formed at some distance from the original wound, either deeply in the hemisphere or in some distant region of the brain not touched by the primary wound.

They developed very frequently around bony sequestra which had not been taken away at the first operation, or under a necrosed fragment of the cranium. In a small proportion of cases they had developed around foreign bodies retained within the cranium.

Abscesses seem to develop with especial frequency as a secondary complication of wounds which had involved the orbit or the ethmoid region; in fact, in a large proportion of these which developed later, the infection was secondary to a sinusitis, or osteitis or to necrosis of a sinus wall. The development of an abscess was announced generally by headaches, vomiting, œdema of the papillæ and slowing of the pulse, and by the usual signs of increased intracranial pressure. Nevertheless, the absence of œdema of the papillæ was frequently noted, and in many cases drowsiness and lethargy, with an increase of local symptoms, were more pronounced than headache and vomiting. A slow pulse was sometimes the most significant indication of a rapidly increasing abscess. However, in many cases the abscess did not manifest any sign which revealed its presence. One man, for example, who had been excused from all work, fell suddenly one night in a theatre and died after a few hours. Postmortem revealed a large abscess in the frontal lobe at a considerable distance from the initial wound.

Operative intervention was resorted to in most of the cases, but the results were not satisfactory. Out of 37 cases, 28 terminated fatally, 9 of them immediately after operation. In other cases death was due to meningitis, to rupture of the abscess into the ventricle or to a progressive encephalitis; in certain non-operative cases the results of intracranial pressure. The best method of treatment has consisted in puncture or evacuation of the abscess by a small incision followed by drainage. Infection appeared to be less virulent when the abscess developed as a late secondary complication.

Meningitis.—While primary meningitis is the most serious complication and the most frequent cause of death in the first period of brain wounds, it is relatively rare in the later course of such wounds. It is, however, a common consequence of intracranial abscess when such abscess has not been operated upon in time, or when the operation is followed by shock. In many cases the meningitis was the result of rupture of an abscess, or extension of the infection to the ventricles. In the greater proportion of the cases of meningitis which survive to the late stages of evolution following gunshot wounds in the head, the infection originated in infected sinuses or in necrosed bones of the orbit, or in the ethmoidal region. In two cases of primary meningitis cure was obtained in both, the diagnosis was confirmed by lumbar puncture and both were treated by the repeated removal of large quantities of purulent cerebrospinal fluid.

Encephalitis.—The sudden appearance of acute symptoms, or the exac-

erbation of existing symptoms, has been attributed in many cases to an encephalitis, but in the absence of anatomo-pathologic examinations, it is difficult to say whether this diagnosis was exact or not. However, there is no doubt that general symptoms, such as headache, and vomiting, associated with the appearance of the evident increase of local cerebral troubles, supervene from time to time, which cannot in much probability be attributed to the formation of abscess, for they disappear generally with appropriate treatment and do not return. In three cases death was attributed to encephalitis, but autopsy was made only in one case. In this brain there was revealed a diffuse and inflammatory softening without any formation of pus at the deeper part of the original wound. In one of these cases there were foreign bodies in the brain.

The clinical distinction of encephalitis from abscess is evidently difficult and uncertain, as when encephalitis exists, the headache is less severe and less persistent, and the vomiting and neuritis less frequent.

By reason of the uncertainty of the diagnosis in most of the cases, it is difficult to determine as to the best treatment of encephalitis. Frequently the symptoms give way after the extraction of bone or of foreign bodies situated superficially and accessible, which had been retained in the brain. Sometimes many patients healed rapidly after a simple exploratory operation, although neither pus nor foreign bodies were found. In other cases the symptoms disappeared with absolute rest and the application of ice to the head.

Infection of the Cerebral Ventricles.—The extension of the infection to the cerebral ventricles is one of the most serious complications of gunshot wounds of the cranium. They supervene often in cases in which cerebral hernia has developed with much loss of cranial substance. In such cases the lateral ventricle is generally dilated and forms a part of the hernial projection, and, if the latter is infected, or if septic encephalitis develops in the neighborhood, the infection extends to the walls of the ventricle and also to the cerebrospinal fluid. As a rule there results a generalized ependymitis, but sometimes the infected ventricle becomes shut off from the rest, and at post-mortem examination one finds it carpeted by a pyogenic membrane which contains purulent liquid. In some of these cases the infection appeared to have become localized and quiescent. The ventricles may also be infected by the rupture of an internal abscess. This invariably results in a generalized meningitis and death.

The surgical treatment of ventricle infection is not encouraging, but if one makes a diagnosis with some probability, it seems that in the cases of localized infection treatment might be attended with success. Among the 2357 cases of this statistic, there were 13 cases in which cure had followed rupture of the ventricle with an hernia, or by an operation practised for the purpose of evacuating a large quantity of cerebrospinal fluid. The greater number of the cases, however, with open ventricles died in a short time from meningitis or generalized ependymitis.

Cerebral Hernia.—As a rule, hernia is to be looked upon as an early complication of wounds of the cranium and of the brain, but as this hernia persists often for months, or may develop later, or as a consequence of the original wound of the cranium, or after secondary operation, it may also be considered as a late complication.

If one examine a large number of records as to the later course of head wounds, or if cases seen at the beginning were followed throughout their later course, one would see that the majority of cases which are accompanied earlier or later by large cerebral hernia have terminated more favorably than one would have thought. Out of 90 patients followed up, who had been the subject of large hernias and whose later course it had been possible to watch during a considerable period, 70 were completely cured and only 20 succumbed. Furthermore, the most of those who died owing to meningitis or to infection of a ventricle survived for the first two months after the wound. All these cases were operated upon very soon after being wounded.

The treatment of cerebral hernia varies in the different hospitals in England. Generally, simple aseptic or antiseptic dressings are applied and this is the method which has been the most successful. In other hospitals the application of astringent agents such as ninety per cent. alcohol or formol five per cent., or even in stronger solution, has been made use of. Surgical intervention properly so-called, has been almost uniformly unfavorable, but when the brain contains fragments of bone or splinters of projectiles, these should be taken away and the abscess or diffuse collections of pus should be opened and drained. In such operations it is important to limit the incision to the inflamed parts and to protect the other parts of the brain from infection.

At the beginning of the war a considerable number of hernias were resected in certain hospitals in England, but the results were disastrous, for the dilated ventricle was opened into frequently and meningitis and ependymitis resulted. Nearly half of the deaths are attributable to cerebral hernia in which the protruding brain substance was removed. The most striking cures followed contralateral decompression which relieves the tension of the hernia so much that the neighboring œdema lessens and permits better drainage.

Epilepsy.—Attacks of general and of Jacksonian epilepsy are very frequent in the earlier periods of cerebral wounds, but they persist in only a small proportion of cases. These disappear frequently after the escape of pus and the subsidence of inflammatory foci.

At the present moment it is impossible to estimate the frequency of epileptic attacks as later complications of wounds of the head, but certainly they appear to be present less frequently than one would have thought. They have generally been attributed to sequestra or to foreign bodies which produce around them an inflammatory reaction, but in most cases no foreign body is found in the brain. It is probably the cicatricial tissue which

develops about the wound of the cerebral substance which is the real cause of the attacks.

Epilepsy is observed after all kinds of head wounds. The brain was wounded directly in most of the cases which we have noted here and almost all these cases have been operated upon a little time after the wound; but attacks have been observed in other patients in whom there had been no appearance of fracture or of depression of the cranium, in which cases they appeared to be the result of cerebral commotion.

Post-traumatic surgical treatment of epilepsy is notoriously unsuccessful. When there are abscesses about foreign bodies in the brain, operations should be attempted, and this frequently prevents return of the crisis. Other surgical measures have not appeared to give any more satisfactory results.

Many cases may be relieved by the administration of bromides. It is the custom in some English hospitals to give moderate doses of the bromides to all men who are received with wounds of the head, and the administration is continued during the whole sojourn of such patients in the hospital. This treatment seems to be very efficient in lessening the frequency of the epileptic attacks.

Mental Troubles.—Slight mental troubles are very common as primary symptoms of gunshot wounds of the brain. Mental depression, slight irritability, forgetfulness, and even mild dementia may persist for long periods. The more grave mental troubles which demand treatment in special hospitals are very rare. Ten cases of such character have been noted from among the 2357 under examination. Two cases of transient mania from which the men rapidly recovered; in another, insanity with illusions was manifested, but was probably independent of the cerebral lesion. The others were depressed and melancholy or irritable, irresponsible and subject to acute attacks of excitability with illusions and hallucinations. Four among these recovered quickly. Such mental troubles were in most cases results of severe and extensive wounds, principally of the frontal lobes. Six of them had been operated upon immediately after having received their wounds; but the seventh, who suffered various obsessions, had only a small fracture which did not involve the brain or its membranes. This patient was also trephined.

Extensive Losses of Substance of the Cranial Wall.—A large proportion of the patients had large losses of the cranial wall as the result of wounds or of operation. Practically none of these, however, complained of symptoms which could be attributed to the breach of the cranial box. A large number of men who had had a ball in the head complained more or less constantly of a group of symptoms that our French colleagues have called the syndrome of the trephined ("le syndrome des trepannes"): headache, which may be general, but most often especially severe in the region of the wound, vertigo, amnesia, inability to concentrate the attention, and insomnia. These symptoms are observed, however, in all forms of cranial wounds and may be also notable and persistent after wounds only of the scalp or linear

fractures of the cranium. Again, in cases with much loss of cranial substance they may be recognized as the result of simple exposure of the brain. Some of these patients, moreover, complain of attacks of dizziness and are prone to faint when they have raised or lowered their head suddenly in a rapid movement, but this symptom gradually passes away with time.

The principal inconvenience of loss of substance of the cranium is the danger of injury to which the unprotected brain is exposed. To remedy this danger plates or grafts of bone have been inserted in only eight of the cases included in the present statistic and in one of these it had to be taken out in consequence of the headache and suffering which it produced. The English surgeons prefer to substitute for such plastic agents a special external metallic protector, generally of aluminum, which is to be worn when there is any danger of receiving a stroke upon the head.

Secondary Effects of Splinters Retained in the Brain.—One hundred and sixty-four men having balls or fragments of shrapnel retained in the brain have been examined. All have been followed at least three months after the wound and 95 of them have been examined as late as two or three years after the wound. Twenty-three of the total number returned to active service in the army; 129 have been invalided, of whom the majority complained of the effects of their cerebral lesions, but 36 of these patients had taken up occupations in civil life; 12 had died, 8 of the 12 deaths supervened within six months after the wound. When the cases of mortality were analyzed, it was perceived that in the last 2 death had followed almost immediately the shock of operation undertaken for the purpose of removal of the splinters; in 3 it was attributable to abscesses which were not successfully treated. In 1 case, to meningitis, and in the others the causes of death were not determined.

The average mortality of these cases (7.3 per cent.) is noticeably greater than that for the total number of cases which were followed for more than three months after the wound (4.7 per cent.); but if it is considered that the splinters had made large tracks through the brain, that they were generally infected, the difference in percentage is much less than would have been expected.

As to the secondary complications, abscesses were the most important. They developed in six cases which is a proportion larger than that noted in the general statistic. Three of these patients died and three survived and healed after the evacuation of the pus and drainage. Some cases develop symptoms of encephalitis, as indicated by abnormal intracranial pressure generally associated with an increase or with the appearance of local symptoms. Some are operated upon without pus, or evident pus formation, being discovered. In some cases foreign bodies were removed, but whether that took place or not, the symptoms disappeared rapidly after the operation. In other cases the symptoms disappeared when the patients were subjected to complete rest, but only to reappear when normal life was resumed.

Nine of the 164 patients had had one or more epileptiform convulsive

attacks, but it is not yet possible to say whether the proportion of such cases is greater than it would be among men who had had penetrating wounds of the brain without a foreign body being retained. There is, however, no doubt that in the great majority of cases balls or fragments of shrapnel may remain in the brain without producing either accident or symptom, if they are not septic. In general, functional troubles are more rare than in those cases which are due to anatomical lesions produced by the wound itself, and not by the presence of the foreign body. Consequently, granted the dangers of operation when the fragments are deeply buried in the brain, one should not attempt to remove them unless there are symptoms of irritation or progressive disease.

GOSSET ON FUNCTIONAL RESULTS OF OPERATIONS UPON PERIPHERAL NERVES *

GREAT difficulties attend any effort to gather the final results of operations on the peripheral nerves. These difficulties are due to the long time required to obtain a cure and the dispersion of those who have been operated upon, which unfortunately has too often interfered with the proper continuity of the treatment. In future statistics it will be necessary to divide the cases into two quite distinct groups according as the operation upon the nerve trunk may have been practised late, after several months, or may have been done immediately after the wound, when a primary or secondary union of the wound had been practised. Data as to results which these immediate operations upon the nerves may give are unfortunately still rare, the operations having been too recent for the most part and above all since the records of the cases which have been subjected to operations upon the nerves in the hospitals at the front have not been sufficiently complete.

It is to be acknowledged also that the statistics which we have at the present moment, which have only to do with operations upon the nerves done late, involve large elements of error. The percentage of successes as reported is less than what it is really, for in a certain number of patients lost from sight and recorded as failures, it is probable that some after their departure from observation develop signs of nerve regeneration. The reporter had a very marked example of this fact. In visiting a fort in the neighborhood of Verdun he found in command there an officer upon whom he had done in March, 1916, a suture of the internal popliteal branch of the sciatic nerve for a loss of substance, 7 cm. in length. He here had the satisfaction of finding in this officer a complete restoration of all the movements in the area supplied by this internal popliteal nerve, except adduction of the tip of the foot. This regeneration had taken eight months to be accomplished. Now, this case which is a fine successful result of nerve suture had been marked upon his records as a failure, and it is by chance

* *Comptes-Rendus de la Conférence chirurgicale interalliée pour l'étude des plaies de guerre.* 3e Session, 5–8 Novembre, 1917.

only that he can register its ultimate fortunate result. In this case the wound had been sustained on the 7th of September, 1914, and the suture was done on the first of March, 1916, 18 months later.

The liability to record an operation as a failure is more frequent, since in a certain number of cases the favorable result does not begin to show itself until after two years or more. As, for example, in the case of a soldier who was wounded on the 4th of September, 1914, who was operated upon at la Salpêtrière on the second of December, 1914, there was complete division of the sciatic nerve with fibrous degeneration of the two ends; after wide refreshing of the two ends and suture, there was after a year no return of motility, but only signs of returning sensations since the 3rd of March, 1915. In December, 1915, good muscular tone was noted. In January, 1916, voluntary motility had returned in the triceps of the calf and in the posterior tibial; the patient walked much better, and in the beginning of 1917 the muscular power was improved and improvement was continuing. Here, then, was a case in which suture of the sciatic nerve showed no tendency to functional restoration at the end of nearly a year, in which after two years it had become noticeable and the improvement was continuing.

The data forming the basis of the present report the author has derived from replies sent by different neurological centres to a questionnaire which was addressed to them from the Service de Santé. These replies give the results of operations done upon 1340 nerve trunks.

Brachial plexus	54 cases	Sciatic nerve	135 cases
Median nerve	191 cases	Internal popliteal	42 cases
Radial nerve	436 cases	External popliteal	106 cases
Ulnar nerve	369 cases	Crural nerve	7 cases

The author had further inspected the records of 11,986 wounded men who had been invalided on account of lesion of the upper limb and 21,052 invalided for wound of the lower limb. He had also been able to avail himself of the personal records from the different services which he had personally directed from the beginning of the war, especially at la Salpêtrière and at Buffon, where had been done by himself and his assistants, and his colleagues, Chutro, Jean Berger, Pascalis and Charrier, exactly 671 operations upon peripheral nerves.

Finally, he had availed himself of a certain number of publications upon the special point of late results after operations upon the peripheral nerves for gunshot wounds.[1]

In an attempt to appreciate the ultimate results of operations practised on peripheral nerves it is necessary to separately consider each nerve trunk, for the experience of this war has shown, in effect, that the operative results are not identical. For example, the case of the radial nerve is not that of the ulnar nerve. And for each nerve also it is necessary to specify the nature of the anatomical lesion and the operation which has been done.

[1] Wiart, Walther, Mauclaire, Auvray, Duval, Tuffier, Mouchet, Benisty.

Therefore, there must be stated seriatim the results for the radial, the ulnar, the median, the musculocutaneous nerves of the arm, the brachial plexus, the internal popliteal and the external popliteal branches of the sciatic, the anterior tibial and the posterior tibial and the crural nerves. The purely sensitory nerves also require separate consideration.

It is necessary further to take into account the time which had elapsed between the wound and the date of the operation and above all the time elapsed from the date of the operation to the moment when the patient has been seen again. Several months, five or six at least, are necessary in the most favorable cases to begin to appreciate the therapeutic results. For certain nerves, such as the sciatic trunk, it takes 15 to 18 months and even two years and more, to accomplish the progressive regeneration of the nerve and its functional restoration.

In statistics of operative results for each nerve it is necessary to take into account, also, the nature of the anatomical lesion and of the operation which has been done. From the point of view of the nature of the lesion, there should be considered (*a*) incomplete division; (*b*) complete division with fibrous continuity; (*c*) complete division without fibrous continuity. The results also should be checked up according to whether the operation was one of liberation, partial suture, complete suture after free resection, or graft.

In stating the results it is necessary to agree upon a terminology which will not involve confusion. The patients should be classified after the elimination of those who have been lost sight of, or who have been operated upon within six months, under the headings of *improvement, very great improvement, and cure.*

Under *improvement* may be classed those where there is a return of sensation or muscular tonicity, or a reappearance of some mobility, whether voluntary or under the stimulus of the faradic current. As *greatly improved* when voluntary movements have returned almost completely, whatever may be the condition of sensation and electrical reaction. As *cured,* when all the muscles have regained voluntary contraction, although there may still exist some defect of sensation and electric reaction.

To appreciate the return of voluntary movement of certain groups of muscles is not always easy unless observers are careful to eliminate certain causes of error and particularly supplementary movements which might make one think a complete functional restoration had taken place, when such movements were due to muscles innervated by other nerves. Surgeons cannot be too careful to guard against such errors into which they often fall.

One may properly employ the word cure only when the patient has the power to accomplish voluntarily certain simple movements which the neurologists have pointed out as requisite in order to guard against mistaking false restoration through supplementary means.

Thus, in his report to the Congress of Neurology, Professor Pitres, of Bordeaux, insisted upon this great cause of error and proposed to adopt a certain number of criterion signs so simple that their use might be available

to every practitioner, and so characteristic that their determination might be considered in each case in particular as a sufficient test to demonstrate the functional restoration of the wounded nerve. As it is chiefly at the extremities of the limbs that the areas of distribution of the nerves become overlapped in a complex fashion and muscles supplied by the different nerves are susceptible of developing these false supplementary restorations, it is in the movements of the hand and of the foot that should be found the tests of the cure of the paralysis resulting from a wound of the radial, the median, the ulnar, the sciatic nerves and their branches.

The tests proposed by Professor Pitres and which have been adopted are as follows:

For the *radial,* the recovery of the power of extension of the wrist and of the fingers, including the thumb, and the supination of the forearm. The patient who can put his upper limb in the attitude of taking an oath, the thumb extended and separated from the index finger, then without changing the position of his arm can bring his hand into a position of supination, is certainly cured of paralysis of the radial nerve. A second test, still more simple, is to place the patient upright facing front, the little finger upon the seam of the pantaloon, the palmar face directly forward.

For the *median* nerve, a ready test consists in the patient placing the hand flat upon a table and asking him to scratch the wood of the table with the nail of his index finger without moving his wrist at all. An excellent sign also is the sign of the fist which demonstrates very certainly the functional activity of the median nerve in the innervation of the muscles of the thenar eminence. In the act of closing the fist, in applying the palmar face of the thumb upon the back of the middle or of the fourth finger, there is brought into play the short abductor, the opponens and the short flexor. Patients who can make supplementary movements of the short abductor through the ulnar nerve cannot execute this movement.

For the *ulnar* nerve the movement of separation and approximation of the fingers, or more simple lateral movements of the middle finger alone, and the movement of flexion of the third phalanx upon the second at the level of the two last fingers present a certain proof of functional restoration of the nerve. It is sufficient to ask the patient to put his hand upon the table upon its palmar face and to carry the middle finger outwardly or inwardly, or to scratch the wood of the table with the nail of the little finger without bending the wrist.

The test for cure of the sciatic nerve or its branches is derived from the execution of simple movements of the foot. The patient being seated upon a chair, the feet resting flatly upon the ground, he is asked to execute the balancing movement in which he will rest alternately upon the ball of the foot and upon the heel. If his internal popliteal is alone paralyzed, he cannot raise the heel above the ground, but can very easily raise the point of the foot and carry it outward or inward. If he has paralysis of the external popliteal nerve, the conditions will be reversed. He will be able to

raise the heel, but he will be incapable of raising the ball of the foot from the ground. When he has become cured, he will be able to execute easily the alternate movements of balancing on the foot.

When these tests are complied with we shall have then a "cure." When there shall not be complete cure, but return of most of the voluntary and electric movements, we say there is a "great improvement." And finally, when there is return of sensibility more or less extensive, return of tonicity and some contractility, either voluntary or electric, we say simply, "improved."

I. *The Radial Nerve.*—Pursuing the study of each nerve by itself, the author first gives the results of 436 operations practised upon the radial nerve which have been sent in from the neurological centres. In 220 cases there was compression; in 13 incomplete division, in 203 complete division.

The operations done have been in 235 cases liberation; 190 cases suture.

Liberation and suture, for unfortunately the distinction is not always made, have given together 25 per cent. of improvement and of cures, 42 cures out of 235 liberations and 10 cures after 190 sutures.

The personal statistics of the author are as follows: Total number of operations done 144, for which 41 done too recently are to be eliminated, leaving 103 cases. Of these, 56 times there was compression, twice incomplete division, 14 times complete division without fibrous continuity, 31 times complete division with fibrous continuity.

1. The cases of *compression,* either by involvement in a callus, 14 cases, or by inclusion in a fibrous mass, 42 cases. Eleven patients have been lost sight of, one operated less than 10 months. Of the 44 remaining, there were 8 negative (18.2 per cent.). In 59 per cent. of the cases the results were very good or perfect.

2. *Incomplete Division.*—Two cases, one negative and one great improvement.

3. *Complete Division.*—Forty-eight cases: with fibrous continuity 34 cases, without fibrous continuity 14 cases. In 42 cases free resection was made of the fibrous tissue at each end, and an end-to-end suture was done, taking care to suture only the neurilemma. Six times, because of too great separation between the two nerve ends, it was necessary to make a graft, taking the graft from the cutaneous branch of the musculocutaneous nerve of the leg. Of the 42 cases, 12 were lost sight of, 9 were operated upon for too short a time for inclusion as to results. Of the remainder, there were negative, 10 cases (37 per cent.); slight improvement, 1 case (3.7 per cent.); considerable improvement, 9 cases (33 per cent.); cure, 7 cases (26 per cent.).

As to the six patients upon whom grafts were used, three have been lost sight of, and the three others observed at periods of three months, six months and 13 months, were not improved.

The author compares with his statistics those of Dumas in 115 operations upon the same nerve, comprising 18 cases of compression, 41 cases of incomplete division and 56 cases of complete division.

Of the compressions, Dumas' results were negative 6 per cent., incomplete regeneration 11 per cent., complete regeneration 83 per cent. These results of Dumas' after liberation are particularly good.

2. Incomplete divisions, 41 cases. The results have been negative 19 per cent., incomplete regeneration 70 per cent., complete regeneration 11 per cent.

3. Complete divisions, 56 cases. The separation of the two nerve ends 10 cases, with fibrous continuity between the two ends 46 cases. In the divisions with complete separation, although suture was especially indicated, in three cases only has suture been possible to be done with favorable conditions without too great tension of the two ends, with suture of the neurilemma. In three other cases it was possible to accomplish direct apposition, but with much tension, notwithstanding the minimum of resection of the terminal fibrous formations. In two cases a longitudinal plastic of the lower end was made. In one case a similar plastic from the upper end, and in one case the two ends were connected through a space of 3 cm. by a thread of linen.

In divisions with fibrous continuity, the cicatricial bridge was dissected out and the two ends of the nerve freed and protected from later compression by appropriate proceedings.

The results have been for the sutures: negative, 90 per cent.; incomplete regeneration, 10 per cent.; complete regeneration, 0 per cent. For the liberations: negative results, 47 per cent.; incomplete regeneration, 10 per cent.; complete regeneration, 43 per cent.

As an example of complete cure after suture of the radial, the author details the case of a soldier who was wounded on the 15th of September, 1914. He entered la Salpêtrière on the 21st of November, 1914, with a complete total paralysis of all the muscles of the left forearm that were supplied by the radial nerve. He was operated upon one hundred and twenty-five days after the wound, at which time there was found to be present complete division of the radial nerve. The two thickened ends were united by a cord of 3 mm. in length and 2 mm. in width. The lesion was seated at a point above that of the emergence of the branches supplying the long supinator and the radial muscles. After resection of the nerve ends, end-to-end suture was made. Histological examination of the fibrous band and the distal end showed that they contained no cylinder axis. Tonicity began to return shortly after the operation; it was very manifest by the thirty-first day; it was marked by the seventy-third day and continued to increase regularly, and by the one hundred and seventy-sixth day there was noted the first return of voluntary motility, faradic contractility being still absent. On the one hundred and ninety-second day after the operation the radial muscles along the supinator and the extensor indicis voluntarily contracted. On the other hand, the return of sensibility was still defective.

In another case which he presented to the Society of Surgery of Paris, Séance of March 7, 1916, all movements had equally become restored with the exception of some weakness in the extensor of the index. The case was in the service of Professor Marie. He was wounded on the 30th of

August, 1914, by a rifle ball which had fractured the left humerus in the lower third, with immediate radial paralysis. The reporter operated upon the patient upon the 3rd of February, 1915, and found in the external bicipital groove complete division of the nerve without fibrous continuity. The two nerve ends were swollen and separated to the distance of a centimetre. After resection of the two cicatricial ends, he sutured the two nerve ends together with silk; closure without drainage. The return of voluntary motility took place by the last of June, 1915, one hundred and fifty days after the operation. Movements had entirely returned in all the muscles supplied by the radial nerve, although still somewhat feeble in the long abductor of the thumb, the extensor proprius of the index, and the extensor of the thumb.

In a patient of Doctor Babinski there was paralysis of the radial with complete division of the nerve and painful phenomena following a wound which was sustained January 17, 1915. Operation was done three months and a half later, May 31. In September, 1915, the pain had disappeared. By the end of October there was noted a return of sensibility and of the movements of extension. By February, 1916, it was noted in the records that the patient was greatly improved from the point of motion and sensation without faradic contractility. By December, 1916, he could be considered as completely cured and was proposed for auxiliary service by reason of some feebleness of the hand and of the electric nerve reaction.

In a case of suture of a right radial nerve in a child a rapid and complete cure was obtained. The child, ten years of age, presented division of the radial nerve above the point of emergence of the branches of the long sulpinator and the radial muscles, the result of a knife cut. There was no infection of the wound and on the fifteenth day end-to-end suture was done for complete division. All the conditions were favorable and the little patient made a complete cure.

In the case of a lieutenant wounded on the second of July, 1915, and operated upon by the author on the 6th of March following, with free refreshing of the radial nerve, followed by end-to-end suture, and the protection of the nerve by animal membrane in July, 1917, there was found to have taken place functional restoration of all the territory supplied by the radial except in the long supinator, but electrical reaction was still quite defective.

II. *Ulnar Nerve.*—The figures for this nerve, supplied by the neurological centres, are as follows: Total number of operations done, 369. For compression, 174; for division with or without continuity, 195. Operation practised: liberation, 200; suture, 155; graft, 2. The results were reported *en bloc,* without those distinctions which are indispensable, as 129 improvements and 24 cures, one cure after graft; that is to say, improvements 39 per cent., cures 6 per cent.

The personal statistics of the author involve 151 cases operated upon, from which are to be subtracted 48 as too recent for use. The 103 cases remaining are divisible as follows: Compression, 48; incomplete division, 3;

complete division with fibrous continuity, 27; complete division without fibrous continuity, 25.

Of the cases of compression, 48 in number, 47 were cases of compression by inclusion in a fibrous mass, one a case of neuroma. The results have been negative in 9; that is to say, 28.1 per cent.; slight improvement 10 (31.2 per cent.); cure, 4 (12.5 per cent.).

Cases of Complete Division.—One case was negative; one considerably improved, and one patient lost sight of.

Complete division, 52 cases; with fibrous continuity, 27 cases; without continuity, 25 cases. Results: Negative, 17 cases (47.2 per cent.); slight improvement, 13 cases (36.1 per cent.); considerably improved, 3 cases (8.3 per cent.); cure, 3 cases (8.3 per cent.); 11 patients lost sight of. Five operated too short a time to be included in the report.

Certain cases are worthy of being reported in detail: One, a soldier wounded in December, 1914, was operated upon in 1915 for paralysis of the ulnar nerve. There was found a complete division of the nerve, the two ends of which were united by a fibrous cord. After free resection there was placed between the ends a piece of the musculocutaneous nerve. The graft was protected by an envelope of animal membrane (pericardium of a calf). By February, 1916, four months later, no improvement had appeared, but in December, 1917, fourteen months after operation, return of sensibility was evident.

Another soldier who was wounded in December, 1915, was operated in February, 1916, two months later, for ulnar paralysis. The nerve was found completely divided. After the ends were refreshed, an end-to-end suture was done with a protective wrapping of animal membrane. In February, 1917, one year after the operation, both voluntary movements and electric excitability had reappeared in the muscles of the hand and the troubles of sensation were considerably diminished.

III. *Median Nerve.*—Number of cases sent in from the neurological centres 191, divided as follows: Compression, 113; division, 78. Procedures resorted to: Liberation, 126, suture, 63; graft, 2. Results: Improved, 45 (25 per cent.); after liberation, 8 cures; after suture, 1 cure.

The personal statistics of the author in median nerve cases includes 108, of which it is necessary to subtract 28 as too recent for consideration. The 80 cases remaining are divisible as follows: Compression, 50; incomplete division, 5; complete division with fibrous continuity, 16; complete division without fibrous continuity, 9.

1. The compressions were all cases of inclusion in a fibrous mass. The results were as follows: Negative, 3 (10 per cent.); slight improvement, 13 (43.3 per cent.); considerable improvement, 12 (40 per cent.); cure, 2 (6.6 per cent.); 15 cases had been lost sight of and 5 had been operated upon too short a time before the report.

2. *Incomplete Division.*—Five cases. The results were negative in one,

considerably improved in one, two cases have been lost sight of and one operated upon too recently.

3. *Complete Division.*—Twenty-five cases. With fibrous continuity, 16; without fibrous continuity, 9. Results as follows: Negative, 7 cases (43.7 per cent.); slight improvement, 2 cases (12.5 per cent.); considerable improvement, 7 cases (43.7 per cent.). Seven patients lost sight of, two operated upon too recently.

One case was that of a captain wounded on the 22d of August, 1914, by a ball which fractured the humerus and produced a paralysis of the median nerve at the bend of the elbow. The patient was operated upon the first of April, 1915, eight months later. The nerve was found involved in a mass of dense sclerotic tissue from which it was disengaged. At the point of division it was considerably thinned and reduced to a vaguely fasciculated cylinder occupying the external border of the mass. Above the thinning was noted a thickening of the nerve. The nerve was divided above the swollen point, preserving 1 cm. more of the proximal end along the external border. After division below the thin part, suture was applied end to end according to the usual manner. The nerve was then protected by embedding it in a layer of muscle before uniting the superficial layers. On the eighty-eighth day mobility began. The patient could flex the two last phalanges of the index and of the middle finger as well as the second phalanx of the thumb. Pain on pressure of the median trunk could be elicited at the wrist and at the bend of the elbow. The tests of sensibility showed that the zone of anæsthesia was diminished. On the two hundred and fifty-seventh day flexion of the index and of the middle finger is complete. The movements of apposition of the thumb are perfect, the zone of anæsthesia has diminished to a small area in the vicinity of the nail of the index and of the middle finger.

It is interesting to note in this case that histological examination showed that it was correct practice not to keep the fasciculus corresponding to the outer quarter of the nerve, since a fibrous callus occupied the lower part of this fasciculus and would have placed an obstacle in the proliferation of the new cylinder axes of the central end.

Another case demonstrated the late results of nerve graft. A man wounded on the 24th of September, 1914, was operated on the 21st of February, 1916, for paralysis of the median nerve. The nerve was found partially divided and involved in a vague fibrous mass. After liberation of the ulnar nerve and of the median nerve, the fibrous part of the nerve was resected with preservation of the lateral track. Suture end to end was impossible because of the separation of the two ends, so that it was necessary to engraft between the two ends a segment of the internal cutaneous of the arm. By November, 1916, 9 months later, the patient was already much improved, both voluntary and faradic contractility had reappeared in the muscles. This improvement had continued at the beginning of 1917.

Another favorable case of nerve graft was that of a soldier wounded in August, 1914, operated in August, 1915, for paralysis of the median nerve

following a shell wound of the right forearm. The nerve was found divided above the wrist and a graft from the musculocutaneous nerve of the leg was done. At the beginning of 1917 the patient could perceive the electric current at the extremity of the index finger; the reaction of degeneration had lessened in the thenar eminence and the muscles would contract under the faradic current. Although there were not yet any voluntary movements, the case justifies grafting in other cases where suture is impossible.

IV. *Musculocutaneous Nerve in the Upper Part of the Arm.*—Three such cases were reported from the neurological centres, all with fibrous compression. Of these one was reported as slightly improved, one as cured, one as lost from sight.

V. *Brachial Plexus.*—Reported by the neurological centres 54 cases: 29 of incomplete division; 23 of complete division. The procedures instituted in these cases were as follows: 30 cases liberation, 23 suture, one graft. Results obtained: 21 cases improved by liberation; 6 cases improved by suture; 5 cures after liberation; 2 cures after suture.

The personal statistics of the author included 43 cases, 9 of which are too recent for use. The 34 remaining cases comprise compression 28, complete division with fibrous continuity 6.

Compression by inclusion in a fibrous mass gave the following results: Negative, 2 (14.3 per cent.); slight improvement, 3 (21.4 per cent.); much improvement, 7 (50 per cent.); cures, 2 (14.3 per cent.). Thirteen patients have been lost sight of and one was operated too recently for consideration.

Complete division with fibrous continuity, 6 cases. Results have been: Cure, 2 cases (66.6 per cent.); much improved, 1 case (33.3 per cent.). Two patients lost sight of; one operation too recent.

VI. *Sciatic Nerve.*—Number of cases reported from the neurological centres 135, classified as follows: Compressions 46, divisions 89. Procedures resorted to: Liberation, 57; suture, 78. Results: Improvements, 54; complete cures, 2; both of which followed suture.

The personal statistics of the writer comprises 104 cases, 34 of which are recent. Of the remaining 70 cases there were compression 33, complete division with fibrous continuity 37. The results were as follows: Cases of compression by inclusion in a fibrous mass, 33 cases. Negative, 4 cases (21.1 per cent.); slight improvement, 6 cases (31.5 per cent.); much improved, 6 cases (31.5 per cent.); cures, 3 cases (15.8 per cent.); 9 patients lost sight of, 5 operated upon too recently for inclusion.

Complete division with fibrous continuity 37 cases, with results as follows: Negative, 7 cases (38.8 per cent.); slight improvement, 2 cases (11.1 per cent.); much improvement, 9 cases (50 per cent.). Eight patients lost sight of, 11 patients operated upon too recently.

In this class belongs the case, referred to earlier in this paper, of the commandant of one of the forts of Verdun, in whom was done a free resection of the sciatic nerve with end-to-end suture, in whom after eight

months there was a complete return of all movements and contractility by the internal popliteal of the sciatic nerve excepting adduction of the point of the foot.

The case of a soldier showed equally an example of late improvement. He was operated upon in July, 1915, for complete division of the sciatic nerve. He was pensioned and sent home without improvement, but on the first of April, 1917, he wrote that he was able to lower the point of the foot; that is to say, to extend the foot upon the leg. He added that this movement was preceded by sensations of prickling and crawling in the foot, so that it was not until twenty months after the operation that he was able to observe any result.

VII. *Internal Popliteal Branch of the Sciatic Nerve.*—Number of cases reported from the neurological centres, 42: Compressions, 16; divisions, 26. Operations done: Liberation, 21; suture, 17. Results: Improvement, 19 (45 per cent.).

Number of personal cases treated by the author 14, four of which are recent. Of the ten remaining, there were compression 3 cases, complete division with fibrous continuity 7; compression by inclusion in a fibrous mass, 2 cases; by metallic body, 1 case. Results: Slight improvement, 1 case; considerable improvement, 1 case; lost sight of, 1 case. Complete division with fibrous continuity, 7 cases. Results: Negative, 1; slight improvement, 1; much improvement, 1; cure, 1; lost sight of, 1; operated recently, 2.

VIII. *External Popliteal Branch of the Sciatic Nerve.*—Number of cases from neurological centres 106, of which there are compressions, 38; divisions, 68. Operations done: Liberation, 51; suture, 49. Results: Improved, 45; cures, 4.

Personal statistics of the author 44 cases, of which 8 are too recent to be included. Of the remaining 36 there were compression, 16; complete division with fibrous continuity, 16; complete division without fibrous continuity, 4. The compressions were all by inclusion in a fibrous mass. The results: Negative, 3; much improvement, 4; cure, 2. Seven patients were lost sight of.

Complete divisions, 20. Results of operation: Negative, 4; slight improvement, 5; much improvement, 9; lost sight of, 2.

The author relates the details of one man who was wounded September 12, 1914, and operated on the 25th of November of the same year on account of a syndrome indicating complete division of the external popliteal branch of the sciatic nerve in the popliteal space. There was found a complete division of the nerve, with separation of the two ends and cicatricial swelling of the lower end. The separation of the fragments was too great to permit of end-to-end suture. As up to that time the operator had not practised nerve grafting, he decided to double back a portion of the lower end and suture it to the upper end. By the first of June following, that is to say, at the end of two months, voluntary motility reappeared in the lateral peroneal muscles and had increased by September. In November the exten-

sors began to contract and in February, 1916, the patient, although not completely cured, could retake his place at the front in duty which demanded frequent marching.

IX. *Posterior Tibial Nerve.*—Number of personal cases 4, of which there were compression 2, complete division with fibrous continuity 2. The compressions were by inclusion in fibrous mass—one patient was cured and the other lost sight of.

Of the complete divisions with fibrous continuity, the result in one case was negative, one case slightly improved.

X. *Anterior Tibial Nerve.*—Number of cases operated upon 1, compression by fibrous mass, cured.

It happened once for the anterior tibial nerve that he was unable to practise suture because of the site of the lesion, which was situated exactly at the point where the anterior tibial gives off its muscular branches. The same thing happened to him also for the upper branch of the radial nerve in the thickness of the supinator brevis, the lesion, quite extensive, being exactly at the point of the division of the nerve.

Such lesions are not amenable to operative cure and it is necessary in such cases to seek by indirect methods the remedy, at least in part, of the paralytic troubles. Thus, in the case of the radial nerve one may have recourse to tendon anastomosis. Chutro has practised such an anastomosis between the tendon of the palmaris longus and the extensor tendons, which have given him satisfaction. Moynihan has also insisted upon the usefulness in certain cases of such tendon anastomoses to secure the restoration of the function of certain muscles whose nerves are not capable of restoration.

XI. *Crural Nerve.*—Number of cases reported from the neurological centres 7. Compression, 1; division, 6. Liberation was practised 4 times and suture 3 times, with 3 negative results and 4 improvements.

The personal statistics of the author comprise 4 cases, all of fibrous compression. Of these four patients, 2 were lost sight of; one gave a negative result and one a cure.

XII. *Operations upon Trunks Purely Sensory.*—Gosset's statistics comprised 12 cases: Internal cutaneous of the arm, 5 cases; external saphenous, 1 case; cutaneous branch of the musculocutaneous of the arm, 3 cases; internal saphenous, 3 cases.

In all cases there was present pain due to compression, or to neuritis in cases of complete division. Operation has consisted in the free resection of the fibrous mass and of the nerve. The following results have been obtained: 4 cases lost sight of; one slight improvement; 7 cured.

Intervention for the Relief of Painful Syndrome.—The question of painful phenomena in lesions of the peripheral nerve is still very complex. They may be divided into two groups:

1. Where the nerve alone seems to be affected and in which simple liberation of a mixed nerve compressed has caused the pain to disappear. Such cases are very frequent.

TABULAR STATEMENT OF CASES OBSERVED BY M. GOSSET

TABLE 1

SHOWING RESULTS OF OPERATIONS UPON THE NERVES ACCORDING TO THE OPERATION PRACTISED

	In percentages			
	Negative results	Slight impvmt	Considerable impvmt	Cures
1. *After liberation:*				
External popliteal sciatic	33.3	....	44.4	22.2
Radial	18.2	22.8	40.8	18.2
Sciatic	21.1	31.5	31.5	15.8
Brachial plexus	14.3	21.4	50.0	14.3
Internal popliteal sciatic	.....	50.0	50.0	.....
Median	10.00	43.3	40.0	6.6
Ulnar	28.1	28.1	31.2	12.5
2. *After suture:*				
Brachial plexus	.....	....	66.6	33.3
Radial	37.00	3.7	33.3	26.0
Sciatic	38.8	11.1	50.0	....
External popliteal sciatic	22.2	27.7	50.0	....
Internal popliteal sciatic	25.00	25.0	25.0	25.0
Median	43.7	12.5	43.7	....
Ulnar	47.2	36.1	8.3	8.3

TABLE 2

SHOWING DATE OF RETURN OF FIRST VOLUNTARY MOVEMENTS AFTER NERVE RESECTION AND END-TO-END SUTURE

	Minimum	Maximum	Average
Median	3 months	11 months	6 months 23 days
Radial	4 months	13 months	8 months
External popliteal sciatic	7 months	14 months	10 months 23 days
Internal popliteal sciatic	8 months	14 months	11 months
Ulnar	7 months	19 months	11 months 11 days
Brachial plexus	12 months	13 months	12 months 15 days
Sciatic	12 months	21 months	16 months

TABLE 3

SHOWING DATE OF RETURN OF FIRST INVOLUNTARY MOVEMENTS AFTER NERVE LIBERATION

	Minimum	Maximum	Average
Radial	1 day	9 months	3 months 27 days
Brachial plexus	1 month	9 months	4 months 15 days
External popliteal sciatic	15 days	12 months	4 months 21 days
Median	1 month	11 months	5 months 5 days
Ulnar	3 days	11 months	5 months 15 days
Sciatic	1 month	14 months	8 months

Simple liberation of the nerve does not always give complete relief. Scarification of the nerve cicatrix in cases where motility was preserved may be added. In one of the cases of the author such a scarification of the median caused the pains to almost totally disappear in from 8 to 10 days.

2. Aside from the simple cases there are many others much more complex in which the cause of the pain appears to be due to an association of nerve and vascular troubles. It is for these complex cases, the pathogeny of which is still under discussion, that sympathisectomy has been practised, under the theory that such cases are to be considered as an expression of a sympathetic neuritis.

Tests after Surgical Intervention upon Nerves to Determine Whether the Operation is a Failure or if There has been Functional Restoration.—There are certain cases of immediate motor restoration, paradoxical cases, of which pathological anatomy and experimental research give no explanation, but of which there exist some examples.

The rapid restoration of motility the day after, or the next day after, a suture is an idea incompatible with clinical teachings or with those of pathological anatomy or experimental research. After division of a nerve the distal end always degenerates and throughout its whole extent if the division is total. Spontaneous regeneration of the distal end except after full reunion with the central end of the divided nerve rests upon no histological or experimental fact. In order that the peripheral end may regenerate, it is necessary that the new cylinder axes issuing from the central end should penetrate into the cicatrix and innervate it until they enter the peripheral end and traverse it throughout its whole length. The regeneration of this peripheral end is accomplished progressively from above downward, and if the nerve possesses, as in the upper limb, for example, an area of muscular distribution for the forearm and another for the hand, function will begin to return in the forearm segment and will be observed only later for the muscles of the hand.

As to the return of motility before the return of sensibility, this is a fact often noted. During the time, always long, which elapses between the application of the suture and the return of voluntary motility, the time occupying 6, 8, 12, 15, 20 months and more, there exist according to the height of the lesion and the length of the track to be restored clinical signs which make it possible to affirm that regeneration of the peripheral end is going on, and which permit the surgeon together with the neurologist to await with confidence the ultimate restoration of motor and sensitory function in the sutured nerve.

The two chief clinical signs of restoration are: (1) The progressive return of muscular tonicity which modifies the attitude of the limb and permits its better utilization; (2) the appearance of zones of paræsthesia in the territory of skin deprived of feeling supplied by the divided and sutured nerve.

These signs are early. Dejerine has noted the appearance of zones of paræsthesia about the seventeenth, twentieth, twenty-seventh days after suture and a return of muscular tonicity appreciable to the sight in from twenty-five to thirty days after suture.

Another important sign of regeneration is the spontaneous pains radiating along the course of the divided and sutured nerve. Dejerine insists upon the

character of these pains which sometimes assume the character of sensations of bruisings, sometimes of dartings, sometimes of electric shocks, sometimes of crawling. They come on at periods of eight to fifteen days and seem to accompany the steps of growth of the cylinder axes, for their appearance often coincides with a lessening of the zone of dysæsthesia, or with a return of tonicity.

The pains and twitchings, which pressure on the nerve trunk provokes below the suture, are often reported by the subject as felt in the territory of the skin whose sensitiveness has been diminished by the wound of the nerve, and one can follow thus from week to week the progress of the new nerve fibres into the peripheral end. However disagreeable it may be for the patient, the appearance of these paræsthesical troubles, subjective and objective, give pleasure to the neurologist, for they bring to him proof that the sutured nerve is in the way of becoming restored.

On the contrary, the absence of any returning sign of tonicity and the absence of any paræsthesic zone indicate that the restoration of the sutured nerve is not taking place.

As to the Causes of Failures after Intervention.—Renewed intervention after failure has taught, except in cases where the separation was already too great at the time of the first intervention, that many of these failures are due to faulty operations; faulty methods which should be abandoned, as suture *à distance* or suture by doubling back a nerve flap, insufficient resection of the cicatricial nerve-end which has left upon the two extremities of the nerve, or upon one of them a fibrous cap through which the cylinder axes cannot pass, or a suture which, notwithstanding sufficient resection has been done under bad conditions, because the axis of the nerve has not been preserved carefully enough, or because the suture has not been absolutely through the neurilemma, or because the two extremities of the nerve have been too forcibly brought into coaptation with each other, producing thus a turning back of the nerve fasciculi. In order that a suture upon nerve ends which have been properly refreshed may result in functional restoration it is necessary to bring together a group of conditions, the importance of which is capital, and it is sufficient that one of these conditions should be omitted in order to produce a failure. Even in case where suture is done in a satisfactory manner, it may not give desired results because under the influence of traction the sutures may give way. Or again, because the suture well done has not been protected with sufficient care. Here is a precaution of the greatest importance, wide and careful resection of surrounding fibrous tissue and special isolation and protection of the nerve trunk by one of the numerous methods which have been suggested.

Finally, there is a last cause of failure of which it is necessary to think, that is a mistaking of the real nerve lesion. Of this the following is a typical case. In a lesion of the radial nerve by the first intervention the radial nerve was liberated from a fibrous mass; the case appeared to be favorable, but at the end of some months there was no sign of functional restoration. At a

re-intervention it was found that, at a point above the point where the liberation had been done, the radial nerve was completely divided. The two trunks of the nerve were then resected, sutured, and ultimately a good result was obtained.

As to the final results of the operations practised upon nerves during the first years of the war much further information is desirable. Now, however, the question has completely changed its character. It is no longer as a secondary operation that suture should be done in nerves of which functional restoration has not occurred and in which the clinical examination reveals grave lesions, but as an operation to be done immediately after the wound. It is as a part of the primary or secondary closure of wounds that the re-establishment of the continuity of the nerve trunks should be effected.

Gosset has had opportunity to operate upon several nerve wounds in conditions in which it was possible to practise immediate suture. In one case, a soldier was operated upon 53 hours after the wound, for a fracture of the lower extremity of the humerus and of the upper extremity of the ulna. After having made an atypical resection of the elbow, followed by securing the bone fragments together by metallic suture, he found a divided ulnar nerve. The two ends of the nerve, slightly contused, were refreshed and then sutured by four points of silk. The suture was covered in by a plane of muscle. When the patient was transferred a month later, examination showed that there was not yet any motor or sensory recovery, but pains under pressure along the nerve trunk warranted the conclusion that regeneration was beginning.

In another case, that of a soldier who was operated upon two hours after multiple injuries by shell fragments, one of the fragments had entered the left popliteal space and completely divided the external popliteal branch of the sciatic. After refreshing the two ends they were sutured together by four points of suture. On the fifteenth day thereafter examination showed typical paralysis of the external popliteal branch of the sciatic. Three months later the point of the foot fell less than in cases of non-sutured paralysis; loss of tonicity was much less great. There was noted neither circulatory nor atrophic troubles. Five and a half months after the wound, the patient could make the movements of adduction of the foot with elevation of the internal border; the anterior tibial had regained its functions; the extensors had not yet begun to function, the adduction of the foot was not possible; the fall of the point of the foot was less marked; muscular tonicity had reappeared in almost all the muscles; tactile sensibility was absent only in the lower third of the external face of the leg; sensibility to pain was perceptible everywhere, although slightly diminished. The patient halts in walking, but he can raise the point of the foot, which does not drag upon the ground. Electrical examination shows diminution in the reaction of the external popliteal branch of the sciatic nerve and of the muscles, but the return of reaction at the level of the tibialis anticus. To the galvanic current the reaction of degeneration is still clear. There is, then, notable improvement.

From such observations one may conclude that primary suture presents considerable advantages. It simplifies the operative technic, since no adhesions fix the extremities of the nerve. Very limited refreshing suffices to bring healthy cylinder axes into contact with a permeable inferior end whereby are eliminated all those failures due to persistence of the nerve keloid. There is considerable time gained toward a final cure together with advantage to the rapid reëstablishment of the trophic and tonic function of the nerve.

This is the real desirable method of treating wounds of the nerves. Unfortunately, those patients operated upon for nerve lesion at the hospitals at the front will risk being lost sight of, so as not to be subjected to scientific study, unless care is taken to provide them with a special ticket and to direct them to the special centres. But the knowledge gained up to the present warrants the belief that immediate suture of nerves will give functional restorations more frequent, more complete and more rapid.

If nerve suture has not given the percentage of successes one might have hoped, it is because it has been done late, after prolonged suppuration, upon nerve ends separated too far and transformed into fibrous tissue. But nerve suture even done late still has more value in the case of complete division than expectancy, as proof of which the subjoined figures are submitted.

The *Commission Consultative Medicale* which has to do with pensions, or with gratuities to be given to the pensioned, has furnished for study 33,638 records. Of 10,214 wounds of the forearm, without amputation, resulting in pension, there were: 865 wounds of the radial nerve; 1314 wounds of the ulnar; 696 wounds of the median nerve; 870 cases in which there were associated lesions, radial and ulnar, radial and median, median and ulnar, ulnar and median. These 3765 pensioners have nerve lesions which have not been subjected to any operations.

Of 4492 pensioners with nerve lesions of the lower limb, 1420 only had been operated upon.

Immediate suture of the nerves which should be done systematically in the hospitals at the front should prevent in the future any such proportion of pensioners on account of nerve lesions.

JOYCE ON PERIPHERAL NERVE INJURIES

In the January issue of the *British Journal of Surgery*, page 418, *et seq.*, Brevet-Major J. L. Joyce, R.A.M.C.T., contributes a paper devoted to the study of war injured nerves, dwelling mainly on the operative treatment. The material studied includes 150 cases of injured peripheral nerves which were under the care of the writer in a war hospital during the period from May, 1915, to April, 1918. Since the latter date fifty additional cases have been recorded in the same hospital.

The nerves involved were as follows:

Ulnar nerve	23
Musculospiral	18
Median	17
Brachial plexus	13
Median and ulnar	11
Circumflex	2
Posterior interosseous	2
Musculocutaneous	1
Internal cutaneous	1
Suprascapular	1
Ulnar and posterior interosseous	1
Median ulnar and musculospiral	1
Median and internal cutaneous	1
Total nerves of the upper limb injured	92
Trunk of the sciatic	18
External division of the sciatic	12
Peroneal nerve	7
Posterior tibial	6
Internal division of the sciatic	3
Anterior crural	1
Anterior tibial	1
Obturator	1
Musculocutaneous	1
External saphenous	1
Peroneal and posterior tibial	1
Posterior tibial and external saphenous	1
Sciatic trunk left and sciatic external division right	1
Total nerves of lower limb	54
Supraorbital nerve	3
Cervical plexus	1
	4

The number of operations performed was 90, as follows:

Neurolysis (liberation)	39
Delayed suture	23
Total exsection and suture	6
Partial exsection and suture	7
Autogenous transplantation	4
Total exsection and autogenous transplantation	1
Homologous transplantation	1
Double lateral implantation	3
Exploration	6

1. *Nerve Transplantations and Double Lateral Implantations.*—This group comprises 5 ulnar, 1 median, 1 sciatic, and one posterior tibial lesions in which end-to-end union could not be obtained on account of the long gap between the divided ends. Of these, two of the ulnar, and the median, sciatic, and posterior tibial cases, were dealt with by autogenous transplants

from the radial. One ulnar case was bridged by a homologous transplant of the external popliteal nerve. In the two remaining ulnar cases a double lateral implantation of the divided ends into the neighboring median nerve was done.

The following is a brief summary of each of these cases:

CASE I.—Complete division of ulnar and posterior interosseous nerve; subjected to operation seventy-five days after the primary wound. The bulbous ends of the separated trunk were resected until healthy fasciculi were visible. A gap of 2½ cm. persisted even after the wrist had been placed in flexion. This gap was bridged by two pieces taken from the radial nerve each 2½ cm. long. The suture line and transplant were wrapped in Cargile membrane. The posterior interosseous nerve freed from callus and wrappd in Cargile membrane. Ultimate result at end of twenty-eight months, partial motor and sensory recovery.

CASE II.—Complete division of the ulnar nerve from wound sustained twenty-three months before operation. At operation complete section of ulnar nerve found present. Bulbar expansions of central and peripheral segments excised. Gap between the two segments of 3.6 cm. was filled by transplanting one piece of the radial nerve. Ultimate result at end of sixteen months, partial motor and sensory recovery.

CASE III.—Complete division of sciatic nerve, result of gunshot wound of left thigh. Operation nineteen weeks after injury. Complete division of sciatic nerve. Both ends bulbous and involved in large bony callus. After liberation, stretching and resection, a persisting gap of 2½ cm. was bridged by three pieces of radial nerve from patient's forearms. The bridge was surrounded by Cargile membrane. Ultimate result, partial motor and sensory recovery.

CASES IV and V.—Median at the wrist, and posterior tibial above the ankle. In both a gap was bridged with autogenous transplant from the radial. At end of six months in both, some sensory recovery. No return of muscular power.

CASE VI.—Complete section of ulnar. Operated upon six months after injury. Gap of 3½ cm. bridged by autogenous transplant of radial. One year after still complete paralysis motor and sensory. Site of operation exposed by incision. A large oval neuroma densely adherent to surrounding muscles found at upper end of transplant. This bulb when liberated from the compressing scar tissue which surrounded it presented normal nerve tissue in size, shape and consistency. A smaller and similar bulb was found at the lower end of the transplant. Seventy-nine days after this neurolysis, some sensory recovery and progressive sensations of formication had appeared.

CASE VII.—Complete division of ulnar nerve with loss of 12 cm. of its substance at elbow. Operation ten months after injury. Upper and lower segments transposed to front of elbow and approximately by flexion of the joint until the distance between them was 7½ cm. The gap was filled by a segment of the external popliteal nerve previously removed from a case of irreparable injury to the anterior tibial and peroneal branches. Suture lines wrapped in Cargile membrane. Seven months later, no motor or sensory recovery having become evident, the nerve was exposed. A soft spindle-shaped neuromatous enlargement was found present at the junction of the upper segment with the transplant. A second neuroma of similar size was present at the junction of the transplant with the lower segment. No conduction of faradic current through the transplant. The transplant was freed from scar tissue and the wound closed. Two months after this neurolysis, progressive formication below the level of the transplant was developing.

The author commenting upon these cases remarks that Cases II and III show that both sensory and motor recovery do occur after nerve transplantation, although in neither case was recovery complete.

In Cases IV and V improvement had taken place at the time of report and in Cases VI and VII it was evident that the axis cylinders had begun to penetrate into the lower segments. The ultimate amount of benefit to be experienced in these cases is still undetermined. Recovery after a nerve transplantation certainly occurs much more slowly than after an end-to-end suture.

Of the three cases of total lateral implantation only one has been followed long enough to speak of the ultimate result.

> This was a case of shell wound of the left forearm sustained in May, 1915, and operated upon in February, 1916, ten months after injury. Ten cm. of the ulnar nerve were found to have been totally destroyed, and, after resection of the bulb ends from the segments and excision of the intervening scar, there was a gap between the fragments of 13 cm. Approximately one-third of the circumference of the median was divided on the ulnar side at two points 16 cm. apart, and the upper and lower ends of the ulnar segments were respectively implanted into the median at these two points. The next August, six months later, there was no recovery of motor power in the muscles, but appreciable restoration of sensation. At the end of twelve months his medical attendant reported that he was able to close all his fingers and give a good grip, with uniform sensation in both back and front of hand; feeling not quite as good as in his right hand, but improvement still progressing. Nine months later, twenty months after operation, personal report made by patient is that he has nearly all the feeling restored to his hand, the most sensitive being the little finger. The man is still in the army and has a useful hand.

The opinion of the author is that the portion of the median nerve between the lateral cuts acts as a pedicled neurovascular autotransplant and is more likely to succeed than a free autotransplant.

Operative Technic.—The upper end of the nerve is usually defined first and the bulb carefully dissected from the adhesions to the surrounding structures. The lower end is then sought for, found and dealt with in the same way. The intervening scar is carefully excised. All the chief bleeding points are ligated and all of the oozing is checked by gauze pressure, oversewing, and by swabbing out the wound by adrenalin 1 to 1000. The obtaining of a dry wound before proceeding with the next stage of the operation is deemed an important point.

When the wound is quite dry, the gap between the divided ends is carefully measured and a rough estimation of what the gap will be when the bulbs have been resected, and decision made as to the steps necessary to bring together without tension the ends of the nerve left after the removal of the bulbs.

After this has been carried out, the bulb on the central end is first removed in successive slices by a sharp knife until healthy nerve fasciculi are seen protruding from the cut face of the nerve. Similar resection of

the distal segment is made. A tension suture of fine catgut is now passed through the centre of both segments and the ends are drawn together. Two continuous sutures of the finest catgut procurable draw the sheath together, one suture being used for each half of the circumference of the nerve. At this stage the tension suture is generally removed, but if there has been any difficulty in drawing the ends of the nerve together, it is tied and left *in situ*.

The suture line and the nerve for 2½ cm. on either side are then wrapped in Cargile membrane. In some cases a further covering of free or pedunculated flaps of fat or fascia have been used. In other cases the nerve has simply been placed between healthy muscles.

The muscles which have been drawn out of the way by retractors are now allowed to fall into position and the wound is closed with layer sutures.

With regard to the results recorded after work upon divided nerves, it is quite certain that, after delayed suture, complete recovery, in the sense that no differences can be found between an affected and a normal limb, is seldom if ever attained. In the best cases there will remain a dulling of the finer forms of sensation, some slight wasting of the affected muscles, or a greater liability to fatigue on the affected side. In tabulating the results, however, the word "recovery" is used in those cases in which there has been complete return of protopathic sensations, recovery of useful voluntary movements in all the affected muscles, with return of faradic response.

"Considerable improvement" denotes complete return of protopathic sensation, recovery of some voluntary movements in affected muscles, with or without response to faradism.

"Improved" denotes some return of protopathic sensation with or without early voluntary twitchings of one or more of the affected muscles, with or without response to faradism, and definite and progressive formication on percussion over the nerve below the level of the lesion.

"No result" comprises all other cases and includes those that have been lost sight of and those in which sufficient time has not elapsed to estimate the result.

TABULATED STATEMENT OF RESULTS OF NERVE SUTURE

Recoveries	8
Considerable improvement	6
Improvement	8
No result	14
Total number of cases	36

AVERAGE TIME UNDER OBSERVATION SINCE OPERATION

Recoveries	15 months
Considerable improvement	7 months
Improvement	3 months
No result	7 months

Neurolyses.—Neurolysis consists essentially in the exposure of the nerve and in the removal of the causes of compression, such as osseous callus, fibrous masses, or cicatricial band. For all doubtful cases a good and uncomplicated suture is much better than a poor liberation. The thickened portion of the sheath of the nerve must also be removed. To this latter procedure is given the term " capsulectomy."

After such capsulectomy, the next and probably the most important step is to protect the delicate nerve spindle which has been stripped from its sheath, and to prevent its compression by fresh adhesions, or the contraction of new scar tissue. The natural bed for a nerve is an intramuscular space and in every case such space is to be sought for. It will usually be possible to lay the nerve in healthy tissue between the muscles, but in some situations, as, for example, the musculospiral in its groove, the attainment of such a bed for the nerve is impossible. In such cases the nerve is wrapped in Cargile membrane. The finer varieties of the membrane should be chosen. The author has explored four nerves which had been protected with Cargile membrane at respectively three, four, seven and nineteen month intervals. From his observations he concludes that such membrane is absorbed in less than six months, during which time it fulfils its purpose in protecting the nerve from compression and adhesions.

Neurolysis combined with capsulectomy can not be expected to effect a rapid cure except in cases of pure extraneural compression.

In the cases of neurolysis under study, 39 in number, there was complete physiological interruption of the nerve without loss of anatomical continuity, but with no sign of regeneration in the segment below the injury in 17.

Number of cases resulting in recoveries	8
Considerable improvement	6
Improvement	3

The recovered cases comprise 2 ulnar, 1 musculospiral, 1 musculocutaneous, 1 posterior interosseous, 1 sciatic, 1 posterior tibial and 1 brachial plexus injury.

The remaining 22 cases of neurolysis were performed either for incomplete physiological divisions which were not recovering satisfactorily, or for the relief of pain, resulting in recovery, 2; considerable improvement, 6; improvement, 2.

CONCLUSIONS

The writer, as the result of this study, presents the following conclusions:

1. In the majority of cases delayed end-to-end union of a divided nerve is successful, and this method of repair is that of choice.

2. As to the reunion of nerve trunks by suture of bulbs, the value of such method is still unsettled, but is deserving of further study.

3. The anatomical continuity of a nerve deserves the greatest respect.

4. Exploration of a physiologically completely divided nerve should be done as soon as the condition of the wound permits.

5. Neurolysis combined with a capsulectomy of spindle-shaped neuromata has been followed by recovery in most and improvement in all cases in which this has been done.

6. Exsection of a spindle-shaped neuroma is not justified unless failure has resulted from a neurolysis capsulectomy.

7. Nerve transplantations and double lateral implantations of the ulnar into the median of the forearm have been followed with some measure of success, including some recovery of voluntary power in the affected muscles, but recovery is slow and uncertain.

8. Nerve growth takes place from both ends of a divided nerve and from both ends of nerve transplants, but axis cylinders grow down only from the central end.

9. An autogenous nerve transplant of smaller size than the nerve into which it is planted is capable of hypertrophy.

10. Axis cylinders, judged by Tinel's sign, grow at the average rate of 2 mm. per day.

11. Perineural scar tissue constricting young axis cylinders is the most important factor in hindering recovery.

WILLEMS ON MOBILIZATION IN THE TREATMENT OF INTRA-ARTICULAR FRACTURES*

In a discussion before the Interallied Surgical Conference on the 6th of November, 1917, Dr. Charles Willems, of Belgium, after remarking that the symptomatology and the treatment of an articular wound was far from being always the same owing to differences in the degree of gravity of the bony lesion, suggested, as a useful classification founded upon the degree of the bony lesion, the following:

1. Articular wounds with slight bony lesion.
2. Articular wounds with moderate bony lesions.
3. Articular wounds with extensive bony destruction.

In the first two classes, the articular lesion takes precedence over the bony lesion and treatment involves the latter only to a slight degree. In the third variety, on the contrary, the bony lesion is the preponderating element toward which the treatment must be directed above all other things.

I. *Articular Wounds with Slight Bony Lesions.*—In this category are included simple perforations of the epiphysis, whether the perforation be complete from side to side, or incomplete with retention of the projectile in the bone; and in addition, cartilaginous erosions with or without superficial bony chips and losses of substance of muscle; deeper wounds but still limited to a slight extent of surface. All these lesions have this in common that

* Comptes-Rendus de la *Conference Chirurgicale Interalliée* pour l'etude des plaies de guerre. 3d Session, 5–8 Novembre, 1917.

they leave intact the greater part of the articular surface and that they are not accompanied by any line of fracture extending into the epiphysis producing detached or detachable fragments. They are not exposed to any displacement. It is this latter element which gives them their special characteristic and determines the treatment applicable to them.

This treatment is simple, namely, that which belongs to articular wounds without bony lesions. It includes excision of the borders of the wound or the wounds, and resection of the entire track through the soft parts. It involves the removal of splinters, smoothing of the bony wound and finally, the complete closure of the joint without drainage; that is to say, in cases which are seen during the first hours before infection. In other cases it is necessary to leave an opening for drainage.

The later treatment does not differ from that appropriate to cases where the bony skeleton has not been affected. Here the author's practice departs from the generally accepted rules.

Immobilization for every joint lesion is still almost a surgical dogma. It is practised by every one. The bolder surgeons grant, at most, that it is often kept up too long. The author, however, has not only done away with immobilization, but he has replaced it by mobilization, active mobilization. This he believes to be of very great importance. Not only does he do away with immobilization but in addition he obliges the patient to move his joint without delay and without ceasing.

Without entering into a detailed description of the technic of his method, he recalls certain essential rules.

The patient, furnished with a simple dressing not too tight, is encouraged to make movements from the time that he awakens from his anæsthesia. He always obeys, if not at once, at least after it has been insisted upon. As soon as he is convinced that movements are possible and not too painful, he will continue to make them without being asked to do so.

The technic of active mobilization will not be the same for all joints. For the elbow there will be movements of extension and of flexion. For the joints of the lower limb there will be, first, analogous movements; but as soon as the effects of the anæsthesia have passed off, walking should be added. The end to be attained is, in fact, to return the articulation to its function.

The possibility of immediately regaining function is a fact which astonishes whoever is unacquainted with the method. It astonishes also the patient, whose confidence rapidly increases.

Of course, the excursions to which the movements will be carried vary according to circumstances. The courage of the patient, his skill in bringing into action muscles which should contract, are elements which have to be taken into account. The extent of the lesion seems to have much influence.

The rapidity of the cure will evidently be affected by these factors, but it is always much more rapid than when the classical treatment has

been followed. The quality of the cure is also infinitely better, the joint mobility remains intact and the muscular atrophy though not entirely absent is at least reduced to a minimum which does not affect the function.

Immediate active mobilization, according to his experience, has not given rise to any accident. The only incident that one sometimes observes is the production of hemarthrosis which is evidently the result of the lesions and not of the movements. It is interesting to note that this effusion at once puts a stop to the movements, but as soon as the liquid is withdrawn by puncture, mobilization instantly is re-established, which means that it is not the wound which abolishes the function but the articular distention.

The consequences will be much more simple as the lesions of the skeleton are restricted in their extent. A limited loss of substance, even though quite deep, will be followed by less disadvantage than the removal of a chip superficial but extensive.

The most unfavorable conditions are the wide loss of substance from the cartilaginous covering. In such cases he has had much difficulty in maintaining the articular mobility.

The results obtained may be considered as definitive, since he has seen them maintained after long months as complete, and even more complete than at the beginning.

II. *Joint Wounds with Moderate Bony Lesions.*—By the term moderate bony lesions are to be understood those which have caused a detachment of an important fragment of an epiphysis, or which have led to such detachment. Such are fracture lines crossing the condyles obliquely. Even when the fragment is not entirely detached, the injury involves the interarticular line where the fixation of the epiphysis is lessened. Its displacement would have the effect of modifying the form of the interline and to compromise the statics of the articulation.

This class of lesions is much more grave from the point of view of function than those of the first category. It is not that the bony damage is necessarily greater, it is often less. What gives it its character and its gravity is the danger of disturbance of the joint line, a danger which must be guarded against in treatment.

Immediate active mobilization is perfectly applicable to these lesions. It is neither more difficult nor more painful than in the articular wounds of the first category. Quite extensive excursions are rapidly reached and also perfect results can be obtained. When the upper limb is involved, and in particular the elbow, there is, indeed, no special precaution to be taken and the limb may be abandoned to active movements quite as if a small lesion was present. The fracture becomes consolidated after very short delay and function is fully preserved. This important point is one easily verifiable by photographs. The fracture line is never the point of departure for an articular exostosis as is often the case when fractures of the elbow are immobilized. On the contrary, the movements have the

effect of clearing the interline and of directing the growth of callus eccentrically. If some little displacement of the condyloid fragment is produced, it will never be toward the joint, but upward, so that in this case there will never be intra-articular accumulations. This slight ascent of the fragments can be seen very clearly in radiographs taken after the cure.

For the knee a certain prudence is necessary. The movements of extension and of flexion should be begun immediately in bed, but walking should be delayed until the moment when the fracture has reached a degree of consolidation sufficient to remove all fear of displacement of the fragments. This requires about three weeks. As soon as walking is permissible, the further treatment is identical with that recommended in cases of minor lesions.

III. *Articular Wounds with Extensive Bony Destruction.*—In this group the anatomical lesions are extremely variable as to localization, form and extent, but as to treatment they can be brought into the two categories, first, great losses of substance, and the second, comminuted fractures. Whether one has to do with loss of substance or with a comminution, the conditions are very different according as the lesion has affected a single epiphysis or both. We have then, in fact, to consider four groups of fractures, namely, losses of substance of one epiphysis, losses of substance of two epiphyses, comminution of one epiphysis, comminution of two epiphyses.

(*A*) *Extensive Losses of Substance from One Epiphysis.*—There may be a large mass torn away in one or several pieces from one side of the epiphysis in such fashion that the corresponding part of the other epiphysis has lost its contact and bearing. The extent of the joint surface is to that extent diminished and the whole articular static is disorganized.

In the case of the elbow, its functional activity will not be very much hindered because this joint does not have to support strong pressure. There will result simply such a degree of bowing of the limb as shall be needed to bring the separated surfaces into relation with each other. The deformity will not alter practically the function. It is quite different at the knee. Here it is not only a question of mobility, but rather of solidity. Now, it is to be feared that a knee which no longer articulates by a part of its surface will be bent to the side opposite to that where the loss of substance is, and will no longer have the necessary firmness to support the weight of the body. Hence, the opinion held by many surgeons that owing to the bad probable functional result it is not best to seek for cure with preservation of mobility, but to remove the articulation by a primary resection.

This opinion does not seem to the author defendable. He has applied in these cases active immediate mobilization, and his report is that, in cases of injury of the elbow, the patient who has sustained this variety of intra-articular fracture will make the movements of flexion and extension as quickly and as easily as if the lesion had been one of lesser degree. The functional result of the mobilization will be excellent. At the be-

ginning there will be some lateral mobility, but this is lessened by use and finally disappears. Whatever may be the condition, the result will be much better than that of the best resection and a primary resort to such an operation is not to be considered. It will be very rare that it will be found necessary to practise it as a secondary resort if active mobilization in its full degree is used. Some lateral flexure alone prevents the result from being perfect, but such æsthetic imperfection should not justify a resection.

The question is more complicated for the knee. As long as the patient is recumbent, the knees fare exactly as in the case of the less important lesions; flexion and extension may be executed quite as well, but when the patient rises and attempts to walk the knee bends markedly to the side opposite to that in which the loss of substance is present and the patient can not support himself upon the limb.

But this lack of power may be only transient. Give the patient a supporting apparatus, as, for example, a Thomas splint, with a joint at the level of the knee and walking becomes possible. After some days of such exercise, the apparatus may be taken away and the patient will be able to walk without any support. A certain lateral mobility will persist for a certain time, but it will go on diminishing from day to day. Finally, the patient, as a rule, will walk with a movable knee which is sufficiently firm. Sometimes the permanent use of an articulated knee splint is necessary.

What goes on in this joint to overcome the tendency to lateral bending and to abnormal mobility? At the beginning it is the voluntary contraction of the muscles on the side opposite to the lesion which keeps the limb straight. The patient lends himself perfectly to the necessary effort which is at first considerable, but which diminishes rapidly. It is probable that at any given moment the muscular contraction is supplemented by a retraction which takes place in the capsulo-ligementous armament on the injured side, a retraction which serves to strengthen the uniting bands on that side and to produce a more solid fixation of the articulation. Whatever it may be, it is certain that the fibrous tissue which fills up the loss of substance plays little part in hindering the lateral deviation.

In the author's opinion, therefore, this variety of bony lesion does not constitute an indication for immediate resection, the functional result of which can not be compared with the preservation of the length of the limb and of the articular mobility.

It is obvious, however, that this method is applicable only within certain limits of bony destruction. These limits can not be fixed *a priori,* for one patient will get good use out of a knee which would be useless to another. However, there is a maximum limit beyond which the articular contact becomes manifestly insufficient and where preservation of mobility ceases to be desirable. According to the author's experience, such limit is the disappearance of a little less than half of the epiphysis. As

long as there remains, for example, a third of the width, function may be preserved. This conclusion is applicable only to the knee, whether it is the femoral condyle or the tibial surface that is involved. In the elbow more extensive lesions can still be given the benefit of conservative treatment.

In the knee where all of one condyle or half of the tibial articular surface has disappeared, the conservative course still should be tried. Resection should be resorted to only as a secondary measure, if it is found at last that the firmness of the articulation is not sufficient. It may happen that the result is better than could have been expected.

(*B*) *Large Losses of Substance of Two Epiphyses.*—In this class of cases there exists on one side of the joint an extensive loss of substance, while on the side opposite the articulation is intact. There is often at the same time an extensive destruction of the soft parts, so that the bony foyer is freely exposed.

As a principle, the treatment should not differ from that which has just been discussed for cases in which one epiphysis alone is involved, namely, excision of the wound, cleansing of the bony foyer, closure of the joint as far as possible and active immediate mobilization.

The results are not equally good in all cases. In certain cases the evolution will be very favorable and function will be preserved, everything going on exactly as in cases of Class A. In other cases the lateral deviation will produce a functional loss of power which will render resection inevitable. The author is not yet able to decide what anatomical conditions may be compatible with conservation and those which demand resection. The problem is a complex one. It seems that the height of the loss of substance is not an essential element. The extent is certainly a matter of importance, but perhaps not the most so. The coexistence of a great wound of the soft parts with destruction of the elements of the joint are not of themselves of as much importance as might be thought. It seems that the factor which plays the essential rôle is the preservation or destruction of the crucial ligaments.

It would appear that whenever the crucial ligaments are present and as much as half of the articular interline is preserved, it is proper to attempt conservation with active mobilization. If the progress is favorable, the patient will, as far as walking is concerned, pass through the same phases as in the preceding case; at first a supporting apparatus, then stiffening spontaneous support of the limb by muscular contraction, finally, retraction of the capsule and of the ligaments.

As to the question, when should a patient who shall have sustained great losses of substance make an attempt at walking? The answer is, as soon as the wound is healed or is in full granulation. If the experiment is not successful and the patient does not find himself able to fix his knee with sufficient firmness, it will be necessary, without being too hasty, to resort to resection.

At the elbow losses of substance of the humerus and the ulna, or the humerus and the radius, may be treated by primary resection, though less frequently than in similar wounds of the knee, for, even if there persists a slight lateral mobility and a certain degree of bending, the function will not be sufficiently interfered with to justify even secondary resection which would not give any better result.

(*C*) *Fracture with Comminution of One Epiphysis.*—We have to make a distinction here between the elbow and the knee and for each of these joints between the upper and the lower epiphyses.

1. *Knee* (a) *Upper Epiphysis.*—Here is found most frequently one of the varieties of supracondylar fracture en T, or to be more precise, lesions which though complicated can arrange themselves as a fracture en T. There may be comminutions of the condyle with multiple fragments with descent of the diaphysis so that it is telescoped into a condyle or between the two. Whether the condyle is comminuted or not, such cases require careful removal of splinters and the application of an extension apparatus.

From the beginning the patient should execute limited movements of extension and of flexion. At first difficult and quite limited, they become more facile as consolidation progresses, with, for the time being, a diminution in extension.

As a rule, the later necrosis of certain splinters which were at first adherent, or the appearance of an osteomyelitis, may make necessary several repetitions of such splinter removals.

The result after healing, which is long in being accomplished, will differ according to the extent and variety of the injury. If the two condyles are entirely destroyed or it has been necessary to completely take them away in fragments, a shortening will be inevitable and mobility will be slight; but resection would have made the shortening greater.

In all other hypothetical conditions the situation will be still better. Suppose on one of the condyles, preserved in part, there may have been still preserved a greater part of its articular surface which may have been brought into contact with the diaphysis after it has been pulled up by the extension, there would be presented conditions analogous to those produced by the loss of substance of a condyle without fracture. The mobility can be preserved in very great measure. In such a complication the effect of extension is to replace and hold in place the fragments at first separated from each other, and the interarticular line may be seen to be reconstituted more or less completely.

Cases of this class end usually with the preservation of excellent function. The only difference from the simple removal of fragments is that there is here rather a fracture with great displacement and that before permitting the patient to walk, it is necessary that the fracture should have become consolidated. This takes a time variable according to the character of the infectious phenomena that may complicate the healing, but during this time the mobility can be very well kept up and many

times before the bony foyer has become cicatrized, the patient will be walking with flexion of the knee and without support.

(b) *Lower Epiphysis.*—Comminution of the tibial surface of the knee almost always presents the same anatomical status. There will be a vertical division of the diaphysis into several fragments, in the midst of which the diaphysis will have become impacted, with lateral separation of the fragments. The result of this is a widening of the tibial surface and a lack of correspondence between the articular surfaces.

The wounds which accompany the comminution of the upper segment of the tibia are frequently attended with severe infection and extensive necrosis. Such complications are more frequent and more severe even than in the corresponding lesions of the femur. They consequently prolong treatment.

Aside from the care demanded by the wound, treatment should be directed to re-establishing the correspondence between the two cartilaginous surfaces by bringing the fragments together from side to side. No means contributes better to this result than continuous extension. Extension may be made through screws inserted above the malleoli. The extension should be energetic and should be prolonged until complete consolidation, which is often delayed in consequence of the wound.

By such strong and prolonged extension and by resort to mobilization of the knee, there may be obtained excellent functional results such as resection is incapable of giving.

2. *The Elbow.* (a) *The Upper Epiphysis.*—The shattering of the humeral epiphysis may be so complete that after the fragments have been removed nothing remains of the epiphysis. The condition is equivalent to a partial resection and the function will be good provided the loss of substance does not extend too high.

Often the lesions are less extensive and by the side of a partial shattering of the epiphysis there will remain a segment of the articular part in place. In such a case it is necessary after taking away the fragments, to close the wound and to begin immediately active mobilization. This is possible from the first day and function may be very well preserved. The question of primary resection is never to be entertained here.

(b) *Inferior Epiphysis.*—Comminution here will involve more frequently the olecranon with variable degrees of injury to the radius and ulna. The rule is still more *de rigueur* than for injuries of the humeral segments that primary resection should never be resorted to. After toilet, as usual, removal of fragments and, if possible, complete closure, active mobilization is immediately begun. It is done without difficulty and assures the preservation of the function, even when the loss of substance is considerable and there remains little of cartilaginous surface. The treatment does not involve any apparatus and resolves itself into care of the wound and into the active mobilization. The little lateral deviation is of no importance.

(*D*) *Comminution of Both Epiphyses.* 1. *Elbow.*—When comminution is complete, the necessary removal of the fragments is equivalent to a resection and there remains only the indication to bring the bony extremities together. But as long as there remains upon the two epiphyses, or upon even one of them, a fragment containing a part of the articular surface, this vestige of the joint should be preserved. Even though the articular vestiges may be minimal, active immediate mobilization will secure astonishing functional restoration. The method may be employed without fear of consequences, since the fixation of the elbow is a secondary element when compared with this method.

2. *The Knee.*—Here it is different. In the knee it is always necessary to first take into consideration fixation.

When the two epiphyses are broken into a large number of fragments, preservation may still be attempted, if a sufficient number of these fragments have remained adherent and are not certainly bound to necrose. To assure one's self, one should take away the splinters manifestly loose and explore the cavity while making extension. One will sometimes be agreeably surprised to find that large fragments regain their place around a simple central loss of substance. If preservation is possible, one would have a member ankylosed, but not shortened. If, on the contrary, callus does not form, the resection may be done secondarily, or even amputation, when the loss of bony substance is too great.

Primary resection or immediate amputation may be resorted to in cases where the first examination shall demonstrate the impossibility of preserving a sufficient number of adherent fragments, cases in which one could not rely upon any consolidation. But apart from such cases of extreme destruction, one may see fractures en T with shattering of one of the condyles to which is added a vertical comminution of the tibial surface as described above. Apart from the comminuted condyle which should be taken away in whole or in part and the fragments of the tibial plateau which often should be removed with the patella, all the rest may be preserved. Continuous extension will bring into line the femoral and the tibial fragments, and the case will be converted into a fracture with loss of substance, but where, on the side of the preserved condyle, the continuity is not interrupted.

One may see this fracture become consolidated, even with some articular mobility. Wherefore, for the injuries of the two epiphyses where the bony pillar can be preserved on one side, primary resection is not to be justified.

It should be added that conditions are changed when a smash, even partial, is complicated by lesions of the popliteal vessels. In such a case immediate amputation must be resorted to.

The conservative treatment thus outlined demands much time and much care. The consolidation may be still attended with many incidents. Infection of the wound has to be combated; necrosis may necessitate

repeated sequestrotomies, etc. But he who does not permit himself to be discouraged by difficulties and who carries on his work with patience will obtain unexpected success.

Presentation of Illustrated Case.—In illustration of the results of the method of treatment which have been outlined in the foregoing section, Doctor Willems presented before the conference a group of patients, 16 in number, in all of whom active immediate mobilization had been employed in various joint injuries of the most diverse character.

The conditions presented by the patients fully justified the claims made by the author in his paper. In some of them the application of mobilization had been resorted to even when purulent arthritis was present, his idea being less the preservation of articular function than the accomplishment of ideal drainage. Mobility, however, is often preserved by such treatment.

The method in such cases comprises wide opening of the joint on one or both sides and active movements of the joint. The movements should be repeated almost without cessation and are to be driven to the maximum of possible excursions.

The author's idea is that such active mobilization produces in a perfect manner articular drainage which no other means can assure. He says that in every case excepting one, he had been able to prevent ankylosis. Up to the present it is not possible to know positively what are the conditions which make the preservation of mobility possible and what are those which render ankylosis inevitable. The virulence of the complicating infection may have something to do with it. It is probable, also, that the closing of the joint as soon as the secretion has been reduced to a minimum may aid in the preservation of mobility, for it is from the time when the joint begins to become dry that in some cases one sees the tendency to ankylosis being developed.

At the conclusion of his discussion he presents the following summary of the rules which are essential to be followed in carrying out his method.

Active mobilization should be begun without any delay and should be carried as far as the patient is in condition to do it. It should be done without interruption, even to the point of fatigue. This mobilization is not painful in the true sense of the word, it is only laborious, and it is necessary to compel the patient to do it, to tease him if he is lacking in courage.

It is never necessary to add passive movements to the active movements with the expectation of hastening the process.

Patients treated by this method never present any serious alteration of their general condition, even during the early febrile period. They never look like those who have been severely infected. They do not fear movements as do those who are immobilized. Even in purulent arthritis it is striking to note that the joint has not that excessive sensibility which an infected joint presents when it is cared for by immobilization.

BOOK REVIEWS

SURGICAL TREATMENT. By JAMES PETER WARBASSE, M.D. Volume II. THE HEAD: THE SPINE: THE NECK: THE THORAX: THE BREAST: THE ABDOMEN. Profusely illustrated. Octavo, cloth, pages 829. W. B. Saunders Co., 1918.

The second volume of Warbasse's book on Surgical Treatment has promptly followed Volume I. The general merits of the treatise were commented upon in the review of the first volume which appeared in the October issue of the ANNALS OF SURGERY. The present volume maintains the same standard of thoroughness of treatment, clearness of statement and judicious conservatism in the selection of material which was characteristic of the previous volume. The great cavities of the body, the head and the spinal canal, the thorax and the abdomen, form the subject of this present volume and hence contain the marrow of modern surgery.

The position taken by the author as to the treatment of spontaneous cerebral apoplexy is worthy of quoting. He says:

"The indications for surgical treatment are those of pressure. Medical treatment offers much for the prophylaxis of this disease, but little for its treatment. Surgery can do much for this condition which in every respect is a surgical lesion. The blood coagulates quickly and the hemorrhage is usually ended in a short time. The progressive symptoms which continue are the most gradual changes, such as the development of a zone of œdema due to pressure. It is doubtful if the routine measures to lower the blood pressure in these cases are of value; it is certain that they often do harm. The rational treatment of this condition must be worked out, not by combating the lifesaving mechanism for regulating the systemic blood-pressure, but by relieving the increasing intracranial pressure due to the presence of a foreign body.

"Given a case of spontaneous apoplexy with stupor, or coma, flaccidity of the muscles of one side of the body and high blood pressure in response to intracranial pressure, and the other characteristic signs of hemorrhage in the internal capsule on the side of the brain opposite to that of the paralyzed muscles, the surgeon may expose the brain and relieve the pressure by draining the clot focus. The skull should be opened by trephine or burr just below or above the squamous suture. The dura is opened by crucial incision. The opening should be made sufficiently large to expose the lower end of the fissure of Rolando, the lower ends of the two central convolutions and the fissure of Sylvius. The brain will often show œdema or other local evidence of injection and hemorrhage. If not, it should be entered at the prominent rounded eminence of the lower end of the posterior central convolution just behind the lower end

of the Rolandic fissure and above the Sylvian fissure. A trocar and canula of small size should be entered in a downward and inward direction. It should pass sufficiently above the fissure of Sylvius to avoid the island of Reil. By inserting the instrument in the middle of a convolution no vessels are injured. The apoplectic clot should be encountered within two inches of the surface. A soft roll of rubber tissue to serve as a rubber drainage tube should be inserted through the canula. The clot may be expected to protrude itself through the tube.

"Because of the intracranial pressure there may be some troublesome bulging of the brain after the dura is opened. This may be overcome by elevating the head of the table. Lumbar puncture may be required. As soon as the dura is opened the decompression should show itself in improvement in the patient's general condition. The results of these operations have not been collected sufficiently to place the operation upon a definite surgical basis. Most of them have been done too late when, as a result of laryngeal paralysis, inhalation pneumonia has been engrafted. Others have been attempted when the compression had exhausted the vasoregulator centres. But it can be safely predicted that, as a result of experimental work which is now being done, the operation will become an accepted surgical procedure."

Such a formal suggestion as to surgical interference in cases of the cerebral hemorrhage of apoplexy is certainly up to date surgery and is quite consistent with modern ideas of pathology and treatment. We congratulate the author upon having given the procedure a detailed description and a fixed standing in the surgery of the head.

For the relief of intracranial pressure, as in cases attended with meningeal effusion, the imperative indication to provide drainage is recognized and various methods of meeting the indication are fully described, such as lumbar puncture, tapping of the ventricles and drainage of the subarachnoid spaces at the cerebromedullary angle and lumbar laminectomy. As a whole, the section devoted to the treatment of injuries and diseases of the head is most admirable and comprehensive.

It is not necessary to present any detailed analysis of all the sections of this admirable volume. It maintains fully the standard set in Volume I, and will be accepted by all as a trustworthy guide to the resources of surgery at the present time.

SURGERY IN WAR. By ALFRED J. HULL, F.R.C.S., Lieutenant Colonel, Royal Army Medical Corps, Surgeon British Expeditionary Force, etc. Second edition. Octavo, pages 624, cloth. Philadelphia, P. Blakiston's Son & Co., 1919.

This book is a handbook in reality, as well as in name, suited for the daily use of an army surgeon in active work. In a brief, condensed manner and still with sufficient detail, and with much clearness, the lessons which have impressed themselves upon the practice of British Army Surgeons have

been assembled in this book and are published in such a shape as to be convenient for consultation.

The demands of military exigency constitute the primary considerations which present themselves upon every page and control the scope given to every theme. The abrupt termination of active hostilities in November make of it, therefore, a matter of historical interest rather than of immediate importance. As a record of the influence upon surgery which this great war has had, such a book will always be of great interest. Thus, in the treatment of wounds there is a progression stage by stage from the front to the rear, each of which presents special conditions which control the special methods which promise the best results. Thus it is that in the chapter devoted to the treatment of wounds we have first, the first field dressing; next, the treatment of wounds at a casualty clearing station; and third, the methods available at a base hospital. It is most illuminating to follow the progress made in the control of surgical conditions which the increasing duration of combat conditions has developed, as shown by the betterment of the methods of control and methods of prevention, which the last year of the war presented as compared with the first year's record, a résumé of all which this book well presents.

The subjects of tetanus, anærobic infection and gas gangrene naturally receive special consideration, and to each of these subjects a special chapter is devoted.

In the chapter devoted to the subject of shock we recognize the coöperation of Crile. The best methods of overcoming it when already present as the result of wounds and exposure already received, and the methods of its prevention in the course of surgical work which is being contemplated are well summarized.

One of the contributions to practical surgery which the present war has given is that of Trench Feet which also has its own chapter, a subject which now, fortunately, possesses only historical interest.

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